METALLURGIA

THE BRITISH JOURNAL OF METALS.

APRIL, 1933. VOL. VII., NO. 42.

FOUNDRY MECHANISATION

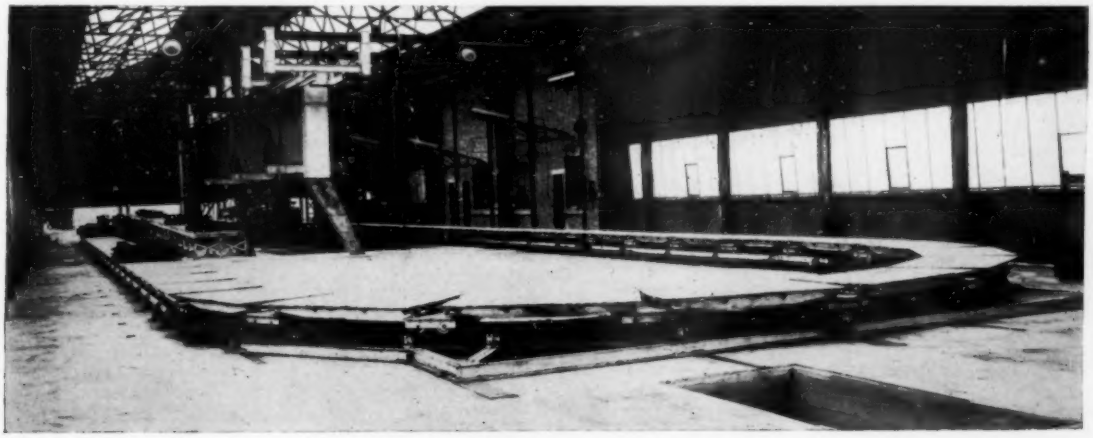
By H. F. Coggon

Thirty or forty years ago mechanical means were replacing human labour in many branches of industry, but it is only during the last decade that any general attempt has been made to adopt the prinicple in the foundry. In this article the author discusses particularly the continuous casting system.

MECHANISM can be defined as the displacement of human motion by mechanical motion. Mechanisation is undoubtedly one of the most vital influences in modern industry, but, whilst it is true that the prevailing tendency of the age has been, and is, to displace human motion, as far as ever possible, by mechanical motion, that tendency is only just permeating the foundry. Thirty or forty years ago mechanical means were replacing human labour in many branches of industry. Prior to, and during, the War there were rapid developments in the machinery of engineering shops, but it is only during the last decade that any *general* attempt has been made to adopt the principle in the foundry. No matter how much one may try to ignore the fact this is definitely the Machine Age.

Mechanisation is, of course, the subject of much bitter controversy which ranges around the multitude of aspects from which the effect of the principle in operation is viewed. Thinkers, writers, and publicists of all descriptions are busy the world over expressing their reactions to this new and rapidly extending force in the philosophy of civilisation. It actively affects everybody in almost every phase of individual life. Every industry, every business, indeed every branch of human endeavour, is affected. It is idle to ignore this new force and to emulate the awe-inspiring example of the ostrich. The machine age would still exist and roll on ponderously. It has been said with infinite truth that necessity is the mother of invention, and dire economic necessity was the mother of the Machine Age and all that it implies in its multitudinous ramifications. It is sheer economic necessity which maintains it; and its future development to its ultimate logical conclusion will be due to the merciless insistence of that economic necessity.

So far as we are concerned this economic necessity expresses itself to us in the competitive selling market, or, more particularly, in the immediate and urgent need for a reduction in the costs of production so that the product of our industry can be sold within the competitive market and still ensure a profitable business. The costs of production are, of course, many and varied, and can be classified and subdivided according to the ingenuity of the cost accountant or the policies of the management. In the foundry it has been said that the castings were made from "metal and labour, mainly labour," a statement which was undoubtedly true of all foundries until recently, and, unfortunately, it is still only too true of the average foundry to-day. From actual analyses which have been made, it has been computed that in order to make and despatch one pound of castings it is necessary to pick up and to put down the equivalent of one pound from something like 150 to 250 times. When one remembers the large quantities of auxiliary materials such as sand, boxes, pattern plates, cores, core plates, etc., which enter into everyday production, in addition to the metal itself, this immense amount of handling becomes obvious. A large number of these handlings is, of course, necessary and unavoidable, but a study of all the operations involved offers convincing evidence that the number, and thus the



A view of a mechanised foundry, showing the continuous-casting system. The August's double bogie type mould conveyer is 400 ft. in total length and weighs over 80 tons. It has a load carrying capacity of over 150 tons. Note the clean conditions. The sand-preparing plant in the next illustration.

cost, of these handlings can be greatly reduced by a little reorganisation and by the introduction of modern plant. Not only can labour be saved, but time and also floor space.

Consider for a moment the ideal conditions. A foundry where the floor is clear, where the atmosphere is as good indoors as out, and where dust, heat, and grime are reduced to a minimum; where hard manual labour is unknown; where, in short, the conditions of labour are conducive to health and decent living; where the guess-work is eliminated from the technique of founding by the control of skill and certainty; where, by reason of all these improved conditions, the product is improved in quality and the cost of production is reduced, with a corresponding increase in output. This is the ideal and may remain only an ideal for some time, but that fact should by no means prevent us from striving to attain it, even if founders individually only progress a short distance along the road. It is realised that only in comparatively rare instances is it possible, by reason of restrictive conditions often beyond the foundryman's control, to go even a fair way along this desirable road; but, on the other hand, almost every foundry can discover instances where the general principle can be applied with a corresponding advantage in economic operation.

A view in the sand-preparing house of a completely mechanised iron foundry where a continuous casting system produces castings at 40 % less cost than formerly. In the foreground the right hopper receives used sand from the shakeout conveyers. Its companion hopper holds new sand. From these two hoppers the correct proportion of old and new sand is fed mechanically on to the belt in mid view feeding screens and magnetic separators from which the sand is elevated to a hopper to a batch measurer which feeds a No. 3 Simpson mixer. The mixed and aerated sand is stored in the 80-ton hopper seen on the right, and distributed, as required, from thence to the foundry again.

The conditions which the British founder has to meet, and under which he has to produce castings, are the conditions which prevail here in Britain, not in America or Belgium, France or Germany; and whilst, of course, we must carefully investigate and watch foundry developments abroad it is as well to remember that it does not necessarily follow that methods and plants found successful in other countries would repeat that success if applied in Britain. This is true, of course, not only of countries but even of districts in a country or even of individual founders. It cannot be over-emphasised that the methods and plants should be designed in relation to the actual local conditions obtaining where the application is to be made. It is undeniably true, for example, that remarkable production figures are obtainable where continuous casting systems have been adopted for the manufacture of, say, automobile cylinder block castings in certain American foundries, but that in itself is no valid reason for the adoption of a continuous casting system in its entirety for their manufacture in this country unless the conditions which guarantee the success of that particular method in America are prevalent here. It is idle to say that cylinder block castings must be standardised to ensure an output sufficient to justify the system, because that is a condition of production over which the foundryman has, as yet, no control. That condition should be impressed upon the buyers of cylinder block castings; at the same time the fact that British conditions differ from the American should not be taken as a valid reason for *not* incorporating as much improvement in method and plant as is economically suited to the conditions here. It may not be economical to install a continuous casting system, but it may pay to improve the method of moulding, for example, or to install a central sand handling plant.

It may quite conceivably be, and very often is, that quite a large percentage of the economies which would accrue from a continuous casting system may be obtained by the accumulated economies resulting from the reorganisation and improvement of the existing methods together with a modernisation of the existing plant.

It seems to be quite clear that there are few general laws upon which the design of foundry handling equipment can be built. There are definite guiding principles which determine the form of this or that part, but the successful design and construction of an efficient plant is very largely a matter of experience—a specialisation in understanding the multitude of varying conditions which exist in all types of foundries, and the design of that plant which a wide experience of all sorts of conditions indicates as being the best to suit the particular set of conditions prevailing in that particular industry.

In the foundry the Machine Age probably reaches its maximum development, so far as it is yet known, in the continuous casting system. It constitutes the complete ideal, which embraces the maximum reduction of the cost of production; the provision of the best working conditions; and the production of the best possible casting by the fullest utilisation of mechanical motion. The essence of the continuous casting system in operation is a definite continuity of successive operations at the highest possible speed, an aim to which all other ends must be subservient; a continuous supply of metal and boxes, of sand, and of cores and moulds.

In its simplest form the continuous casting system consists of a number of definite stations at which certain operations are performed, or necessary equipment or articles supplied, and the connecting together of these stations by means of conveyers along which the raw materials and auxiliaries move through various stages of manufacture to the ultimate completion of the casting. Obviously, a large number of varying types of continuous casting systems are possible, but all subscribe to the same common basic principles. Fundamentally, therefore, continuous casting is an attempt to reduce to a minimum the variable factors involved in founding and their replacements by constants—an end which is obviously attainable only by the standardisation of the necessary definite cycle of operations and its continuous repetition without variation. All the necessary equipment must be designed for the end in view, box parts should be interchangeable, patterns and core boxes must be true and durable, the sand used in the moulding machines must be consistent and uniform, free of all foreign matter, perfectly mixed, blended and tempered. Melting conditions must be arranged so that a continuous supply of correct

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Analysis of B.C.I.R.A. Results Obtained by Form-Factor Method

By A. C. Vivian, A.C.G.I., Assoc. M. Inst. C.E.

An analysis of the test results by the method used shows that the grade of cast iron tested obeyed definite and consistent physical laws, which are capable of exact expression.

THE following article comprises a brief summary of a comprehensive series of tests on cast-iron beams carried out by the British Cast Iron Research Association to check a method of stress analysis developed by the writer.

The test results and the analysis were published recently under the title of "Analysis of B.C.I.R.A. Tests by Form-Factor Method,"[1] and reference should be made to that paper for a detailed account of the method of stress analysis employed, and for the graphs showing the close correlation between measured and calculated results which was established.

The tests and analysis suggest that any particular grade of cast iron produced under controlled conditions has a consistent and comprehensible character, and justify the observation made in a previous paper,[2] that uncertainties which have in the past surrounded cast iron are due to the attempt to interpret the physical properties in terms of a mathematical theory which does not apply. The uncertainties are not due to any intrinsic undependability in the metal itself nor to any capricious "inherent properties."

Dimensions of Beams.—Twelve standard bars were cast and machined to approximately 2 in. × 1 in. cross-section, and were tested on 36-in. centres. Seven of these bars were tested on end—*i.e.*, with 2 in. depth,—and five were tested flat—*i.e.*, with 1 in. depth of beam. Deflection measurements were made on four of the "on-end" bars and on two of the "flat" beams. Six round bars, 0·9 in. diameter, and four tee sections were machined from the broken 2 in. × 1 in. standard bars, and were tested on 18 in. centres; in five cases, including two of the tee beams, deflection measurements being made. The measured breaking load in each case is given in Column 4 of Table I.

Tensile Strength.—Seven tensile test-bars were also machined from broken 2 in. × 1 in. bars. Six of these bars were machined to 0·798 in. diameter—*i.e.*, the standard 1·2 in. diameter bar (B.S.I. Specification No. 321)—and the last was prepared as a standard 1·2-in. bar, except that for purposes of extensometer readings the normal 0·798 in. diameter was reduced to 0·564 in. diameter. The breaking strength in each case is stated in Table II.

It will be noticed that on the standard 0·798 in. diameter bars the apparent strength of the iron varies from 11·85 to 12·80 tons per sq. in., whereas on the bar which was reduced at the test section to 0·564 in. diameter, a strength of 13·80 tons per sq. in. was recorded. With regard to this there exists a good deal of experimental evidence bearing on the fact that the structure of some grades of cast iron weakens towards the centre of a bar, but none that it strengthens, and it was concluded that since the 0·564 in. diameter bar showed greater strength than the thicker bars, the ultimate tensile strength of the iron was at least 13·8 tons per sq. in. The low tensile strength obtained from the thicker bars was considered to be due to shear effect as between the outside and inside of the bar (the load being applied in the testing machine to the outside of the bar only). This would tend to produce non-uniformity of stress over the test cross-section. The maximum tensile strength which would be developed in the beams was taken to be 14 tons per sq. in.

Calculated Breaking Strength of Beams.—The paper referred to gives the formulæ for the theoretical maximum moment of resistance of the various cross-sections tested. A beam of cast iron breaks when the stress on the tension face reaches the ultimate tensile strength of the iron as determined by direct test. All the theoretical breaking strengths stated in Column 3 of Table I. have been calculated assuming a stress on the tension face of the beams at fracture of 14 tons per sq. in. The ratio of the actual breaking strength to the theoretical breaking strength is given in Column 5.

TABLE I.

ANALYSIS OF TRANSVERSE TESTS.

1. Bar No.	2. Shape of Section.	3. Calculated Break Load W max. Tons.	4. Measured Break Load, W Tons.	5. Ratio $m = \frac{W}{W\ max.}$	6. Calculated Tensile Stress, Tons/Sq. In.
Rect.					
1	▮	1·718	1·760	—	14·00
2	▮	1·703	1·40	0·822	13·22
3	▮	1·720	1·675	0·974	13·98
4	▬	0·840	0·710	0·845	13·40
5	▬	0·855	0·810	0·949	13·92
6	▬	0·857	0·795	0·927	13·86
7	▮	1·718	1·420	0·828	13·27
8	▮	1·711	1·6	0·935	13·90
9	▮	1·718	1·640	0·955	13·94
10	▮	1·711	1·520	0·888	13·69
11	▬	0·868	0·8	0·922	13·83
12	▬	0·855	0·702	0·820	13·20
Round					
1	●	0·377	0·410	—	13·00
2	●	0·377	0·403	—	14·00
3	●	0·377	0·418	—	14·00
4	●	0·377	0·4	—	14·00
5	●	0·377	0·375	0·995	14·00
6	●	0·377	0·380	—	14 00
Tees.					
7	⊥	1·98	1·920	0·970	13·97
8	T	1·27	1·205	0·948	13·92
9	⊥	1·98	1·850	0·934	13·89
10	T	1·27	1·2	0·945	13·90

NOTES.

Bars cast green sand moulds. All bars machined. Chemical composition: T C. 3·21, Si 1·75, Mn 0·63, S 0·11, P. 0·98.

Thus, rectangular bars Nos. 2 and 12 broke at a ratio, $m = W/W\ max = 0·82$ approximately—*i.e.*, 18% below the theoretical value and rectangular bar No. 7 at approximately 17% below. The theory shows that these big variations in transverse breaking strength are not so serious as they appear.

Transverse Stress Distribution.—The transverse stress distribution lines across a beam are curved in just the same way that the tensile and compressive stress-elastic strain lines are curved, and in particular the tensile stress-strain line tends to become parallel with the strain axis at high stresses. The corollary is that the stress developed at the tension face of a beam reaches nearly to the maximum value considerably before the bending moment

1 Foundry Trade Journal, March 16th, 1933.

2 "Some Observations on the Character of Cast Iron," London Branch, Institute of British Foundrymen, 13th October, 1932.

approaches a maximum. In the case of the iron tested, the stress analysis shows that when the bending moment is 80% of the theoretical maximum moment of resistance, the stress developed on the tension face is 93·1% of the ultimate tensile strength. When the bending moment reaches 90%, the tensile strength is at 98%.

It follows that comparatively small variations in tensile strength of the metal in a particular beam will precipitate failure at 10% or more below the maximum value. At lower stresses, however, the transverse stress distribution line tends to become a straight line, and an iron which shows considerable variation in transverse breaking strength may be quite reliable at working stresses.

TABLE II.

Bar No.	Breaking Stress, Tons/ Sq. In.	Diameter, Inches.
1	12·80	0·798
2	12·80	0·798
3	12·50	0·798
4	12·46	0·798
5	11·94	0·798
6	11·85	0·786
Extensometer bar	13·80	0·564

It does not, of course, follow that cast iron can be recommended for all purposes. The tendency in the past to employ it for purposes for which test results show it to be unsuitable has not been in the best interests of the material.

The calculated stress on the tension face of each beam at failure is given in Column 6 of Table I. The maximum variation in tensile strength of the iron tested, according to these transverse tests, is from 13·2 to 14·0 tons per sq. in.

Elastic Deflection.—The elastic deflection experiments provide the link between breaking stress and working stress. Rectangular beam No. 7, for example, which broke at 17% below its theoretical strength shows calculated and measured elastic deflections which are for all practical purposes identical. Similarly, the other beams, whether they broke at their maximum values or considerably below, all show reasonably close agreement between theoretical and measured values of elastic deflection. The same physical constants of the iron were used throughout.

It follows that an ordinary grade of cast iron is not unpredictable or uncertain in character, but is, on the contrary, remarkably consistent.

The method of stress analysis which has been used provides the means of assessing quantitatively the fundamental physical characteristics of cast iron.

Wickman's New Premises.

Messrs. A. C. Wickman, Ltd., who have specialised for a number of years on the supply of high-production machines and Wimet brand cutting tools for all engineering industries, have recently moved into new and larger premises in Queen Victoria Road, Coventry, where they will manufacture various machines which have hitherto been imported. The building, which comprises a floor area of 12,200 sq. ft., is adequately equipped for dealing with the work.

The aim of this Company is not only to continue to give every possible assistance in the way of advice on selection, setting-up and mode of operation to the buyer of machine-shop equipment, but to amplify this service. The specific production problems of each customer are analysed and the most suitable tools suggested; and when the order is placed, nothing is considered too much trouble in ensuring that efficiency in use is attained.

Engineers are sent to the customers' works to control the actual installation, and to give advice and instruction on the particular features of the type concerned. After-sales service, too, is given, for customers can always call on this organisation for the elucidation of problems that may arise in actual production.

Foundry Mechanisation

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metal at the correct temperature is definitely guaranteed at the pouring point.

There are three great advantages obtained by the continuous casting system. Firstly, better casting is obtained by rendering constant those factors which, through their occasional variation, caused poor or waster castings. By standardisation the harmful effects of these extraneous influences are removed.

Secondly, cheaper product is obtained because the cost of production is reduced in so many directions.

(*a*) Man handling is reduced to a minimum.

(*b*) All actual productive plant or labour is working at a greater rate, thus increasing its efficiency and reducing its cost.

(*c*) The total standing charges per casting are less because of the considerably greater output which is produced in a less floor area.

(*d*) Further floor area is available for other production.

(*e*) Less labour is required, as all unskilled work is accomplished mechanically.

(*f*) Less equipment in the shape of boxes, clamps, etc., is needed owing to quick release and re-use.

(*g*) Less sand is required.

(*h*) Owing to the sand-cleaning equipment, scrap and small iron is recovered and available for re-melting.

(*i*) By the very virtue of the elimination of variable factors the percentage of wasters is reduced.

The third great advantage of the continuous casting system is that, although less labour is actually used, the labour which is employed can be paid higher wages and can be employed in far better working conditions.

The adoption of the continuous casting system, and thus the fuller appreciation of all that mechanisation has to offer is, of course, entirely dependent upon certain very definite conditions, amongst which are the following :—

The demand for the particular casting or castings of a similar type, size, and weight must be such as to ensure that the total economies in production costs are great enough to justify the initial capital expenditure, and the necessary maintenance charges, involved in the installation of a continuous casting system. Labour must be agreeable to operate the system, be appreciative of the working advantages gained, and be enthusiastic of the possibilities in the system. In this connection it would be as well to say, delicate though the subject is, that Evolution is a sure and inevitable law. The opposition of labour to the introduction of machinery has been a very real factor retarding the development of mechanical aids, and labour's disinclination to assist in the greater efficiency of the foundry has materially encouraged the alarmingly rapid increase in supplanting castings both by fabricated steel work, which is lighter and often cheaper, and also by die castings and stampings.

Tin Research and Aero Engine Bearings.

An important research has just been begun in Manchester into the best bearing metal for aeroplane engines. It is part of a programme of research, instituted by the International Tin Research Council, which represents tin-mining interests in all parts of the world. The work is guaranteed for three years, and should do much to increase the possibilities of long distance flying and reduce the cost by enabling the engine to run longer hours between overhauls. Among the machines installed in the new laboratory, specially built for the purpose, is one which submits the experimental bearings to as much pounding in a few hours as it would receive in flight in the course of as many months. The result should also be of interest to the motor industry, especially for racing purposes.

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Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "Kenpred," Manchester. *Telephone: Central 0098.*

METALLURGIA

THE BRITISH JOURNAL OF METALS.

FOUNDRY PROGRESS.

CONSIDERABLE progress has been made in the application of scientific knowledge to the work of the foundry in comparatively recent years. Acute competition through a long depression has had some effect in causing strenuous efforts to be made to meet the ever increasing need for sounder and stronger castings. Each branch of the industry has found it necessary to seek fuller information about the materials used, the equipment employed, and to strive continually for improved methods of production. It is probable that greater progress has been made during this lean time than would have taken place had there been abundance of work, for then production to meet immediate needs would have been of primary importance. On the other hand there can be no question that the foundry has benefited from the gradual introduction of the skilled metallurgist who has been able to apply the results of many valuable researches to the practical problems of the industry.

It is not possible here even to attempt to refer to all the recent researches that have proved of benefit, but a recent development indicates how rapidly science is being directed to the work of the foundry. This refers to a method of stress analysis developed by Mr. A. C. VIVIAN, which has been tested by the British Cast Iron Research Association. A summary of these test results is given elsewhere in this issue, but the results seem to suggest that any particular grade of cast iron, produced under controlled conditions, has a consistent character and justifies the observation that uncertainties, which have in the past surrounded cast iron, are due to the attempt to interpret the physical properties in terms of a mathematical theory that did not apply. It is claimed that an ordinary grade of cast iron is not unpredictable or uncertain in character, but is, on the contrary, remarkably consistent, and the method of stress analysis devised provides the means of assessing quantitatively the fundamental physical characteristics of cast iron.

The importance of this development to the iron foundry is considerable because it means that the designer can calculate with a greater sense of accuracy, providing the metal to be used is mixed, melted, and cast under adequate control. But, despite remarkable progress in the application of science, founding is not yet wholly scientific; it is still the ambition of every foundryman to produce the perfect casting. True, by seeking to obtain exact knowledge of what is used in the production of a casting—in order that by control and supervision it may be repeated with unvarying success—it brings appreciably nearer the production of castings as a science.

Probably the greatest progress has been made in the production of repetition castings. These provide an opportunity to eliminate the effect of the human factor and in many instances remarkable success has been achieved. This is only possible, however, when operations proceed on a predetermined plan with no variation. It is quite a different proposition when the castings to be made are not of a repetition character, and much of the work of the average foundry is of this nature. For such work individual skill and experience are still necessary and the human factor frequently is the deciding one between success and failure.

Engineers and designers do not always appreciate that the making of sound castings is more complex than the production of almost any other product used in engineering. Each casting presents its own problems. The particular purpose for which it is to be used determines the physical properties required of the metal or alloy, and different metals and alloys each involve a new set of conditions in production. In cast iron, for instance, castings are frequently required in which strength plays a relatively unimportant part; on the other hand a high-duty cast iron may be necessary and, though the principles involved in production are similar, the technique employed is almost entirely different.

Much progress has been made in the development of metals and alloys to meet specific purposes, which has resulted in considerable change in foundries producing light-alloy castings, and in the brass, iron, and steel foundries. In each branch of the industry this development has been achieved by research and careful investigation and the results interpreted into practice. The wide range of alloys in each branch has increased the complexities in casting production; fortunately progress has been gradual, and in many cases it has been possible to modify technique to ensure that the percentage of waster castings can be kept at a reasonably low level. But the application of science has not solved the waster problem, although it has made the production of certain types of castings economically possible and is effective in reducing the percentage of wasters. Each branch has now become highly specialised; even within each branch distinctive sections have arisen, which, for various reasons, are separated. In both iron and steel foundries, for instance, in which alloy castings now have so important a place it is customary to allocate the space in the foundry so as to limit the possibility of error in practice for the grade of metal used. The same applies to brasses and bronzes in the brass foundry.

But the successful pursuit of the foundry industry does not depend upon the application of science to the technique of production only, it depends rather upon the degree of attention given to three main factors. In addition to the application of scientific research, these include economic and industrial conditions and salesmanship. It is in effecting a correct balance between these important factors that progress will be under control. Quite a large percentage of foundries are unbalanced in this respect and cannot understand why some of their competitors are so successful. It is not an exaggeration to say that the future of British industry depends very largely on research work and salesmanship, and it is exceedingly unfortunate that it is not always appreciated how important a part of selling is advertising and participating in industrial exhibitions. Even in times of retrenchment the selling organisation cannot be neglected. With regard to exhibitions it is to be hoped that the efforts of the promoters of the Foundry Trades Exhibition at the Agricultural Hall, London, will meet with full success, but it is extremely regrettable that the number of exhibitors is so small.

"NATIONALISING" THE IRON AND STEEL INDUSTRY.

THE National Committee for the Iron and Steel Industry, constituted on June 3, last year, recently submitted a report of its deliberations together with a scheme for the reorganisation of the iron and steel industry. These documents are not only of great importance to the home manufacturer and user of iron and steel but provide food for thought in manufacturing countries abroad. They contain proposals for the co-ordination of the industry and though, as Mr. Neville Chamberlain stated, in a letter to the Import Duties Committee, only the first stage has been reached and that much remained to be done before the industry can be said to be properly equipped and organised, the preparation of an acceptable scheme for reorganising such a complex industry is probably the most difficult task with which the National Committee will be confronted.

The purpose of the National Committee is to build comprehensive machinery for the industry within which the advantages of both combined action and industrial enterprise may be secured. It is with regard to this machinery that the scheme is primarily concerned. The scheme embraces the formation of twelve associations, each dealing with a group of products co-ordinated by the formation of a corporation which is to be so organised that it will give a reasonable balance of interests to the producing and consuming sections of the industry.

The Committee believe that the orderly progress of the industry can only be secured by the regulation of production in relation to demand, both by international agreements and also even within the protection of the tariff walls, by applying some degree of control to the individual producers of each country. The proposed scheme therefore aims first at setting up an organisation in this country which will have the power to negotiate such arrangements with producers abroad, and will be in a position to apply the necessary degree of control at home to the benefit both of the industry and the nation generally. In regard to the British iron and steel industry, it is emphasised that mere regulation of production in relation to demand will not alone suffice to place the industry in a position to play its proper part in the national economy. The British iron and steel industry reached maturity in the days of individualism, and the continuance of free access to foreign supplies of raw and semi-finished materials has resulted in its retaining much of its complex individualistic organisation long after its competitors in other countries have become highly nationalised. Such a situation might be tolerable in times of prosperity, but under conditions of surplus production the existence of many small, inefficient plants has handicapped others in keeping abreast of their competitors abroad. A considerable amount of leeway both in equipment and in organisation has, therefore, to be made up in various sections of the industry before its condition can be considered to be thoroughly sound.

In order to effect the orderly progress of the industry it is proposed to replace the many existing trade associations within the iron and steel industry, including the National Federation of Iron and Steel Manufacturers, by a much smaller number of associations concerned with the production of various classes of manufactures. Existing associations are to be combined into associations forming the following groups :—Pig-iron and ferro alloys ; blooms, slabs, billets, plates, angles, sections, joists, sheet and tinplate bars, rails and re-rolled products, such as rod, bars, hoop, and strip ; wrought iron in all forms ; special steels in all forms ; steel castings ; forgings ; sheets ; tinplates ; tubes ; wire ; fabricated steelwork. It is proposed that all these associations shall be elegible for membership of a British Iron and Steel Export Association. The work of these associations is to be co-ordinated by a proposed Iron and Steel Corporation of Great Britain which will control production and carry into effect national planning for the industry as a whole.

The general conception underlying the scheme is that the respective associations should be the responsible agents for securing the efficient working of each section of the industry, being each autonomous in its own sphere, and that the functions of the Corporation should be generally of a stimulating and co-ordinating character.

It is appreciated that the ramifications of the iron and steel industry extend into every phase of the national life and, to maintain a tariff on imported iron and steel at an effective level, the Government and Parliament need assurance that the interests of consumers of iron and steel are properly safeguarded. For this purpose it is proposed that the Corporation should contain a considerable proportion of the consuming interests.

Reorganising the iron and steel industry nationally within the industry presents many problems which can only be smoothed when the scheme is in operation. It seems that both manufacturers and consumers are asked to have faith in the proposals at the outset, and to believe that with continued experience of the scheme the difficulties that have retarded development in the industry will be overcome. It is not a particularly hopeful sign that competition in industry should be subdued as this will undoubtedly reflect on individual enterprise. Purchasing redundant plants, which is incorporated in the scheme, is also a questionable proceeding, since, obviously, under normal competitive production, those plants unable to cope with conditions as they are would either need to be modified or cease to operate, and there would be no need to purchase.

THE RUSSIAN TRIAL.

THE sentences on the employees of the Metropolitan-Vickers Electrical Company have just been promulgated as we go to press. This is a technical journal and is non-political, but we greatly deplore, as must our many friends in Russia, the whole unfortunate affair. The new Russia is yet young, and we regard the trial as one of the mistakes of its youth. There are few people in Great Britain who do not believe in the complete innocence of the six Englishmen who were on trial, but it is significant that, despite the indignation that has been freely expressed, the friendly feeling of the people of Britain towards Russia has not changed. The trial is regarded as a ghastly mistake.

Nothing is to be gained by retaliation. Russia has its legal system like all other countries, and cannot be blamed for resenting criticism of it or interference with it. The general belief is that the sentences are unjust, and, from motives of policy, it is inconceivable that they will be allowed to stand. The integrity of British engineering has been questioned, and it should be realised in Russia that the British engineer is proud of his profession, too proud of it to indulge in corruptive methods, and that British engineering concerns have honestly endeavoured to aid Russia in shaping itself into an industrial country ; they have given generously of their skill and experience.

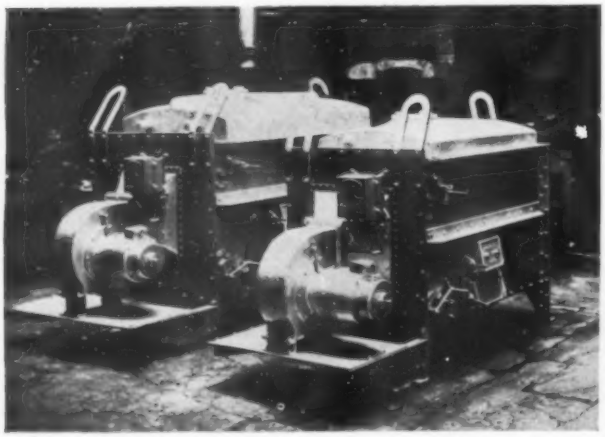
The trial will undoubtedly be a blow to confidence. There will be a natural reluctance for British, American, or German firms to take what they will consider as "risks," and they will not find it so easy in future to get the right men to exile themselves for long periods in Russia. The trial may tend to injure Russia's reputation and make world credit more difficult to obtain, and the leaders of the country must regret, in this case at least, the activities of the O.G.P.U. Secret police are a menace to public welfare in any land.

Tribute must be paid to the splendid attitude of Mr. Alan Monkhouse, who was head of the Metropolitan-Vickers organisation in Russia. His dignified, courageous conduct throughout the trial was simply admirable. He deserves well of the firm whose interests he watched over in Russia, and that country has made a great mistake, for she has need of the services of such men.

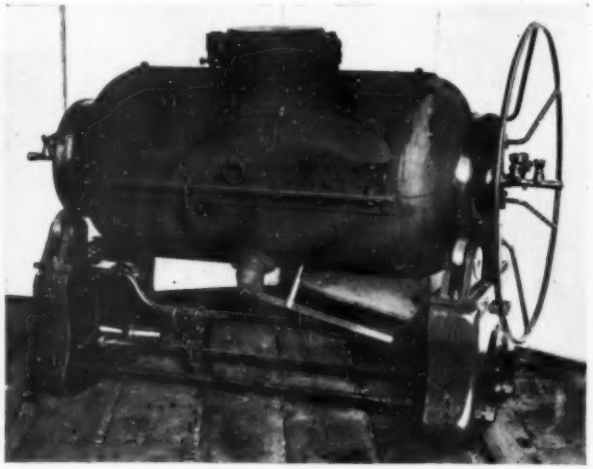
The Foundry Trades' Exhibition

As an indication of progress in the foundry trades it is fitting that an exhibition should be held at intervals to mark the developments made and to bring under one roof materials, equipment, and products of the foundry. It is a sensible idea that these exhibitions should be of an international character, as then those interested can appreciate better the significance of the exhibits. Several factors, however, are responsible for the comparative exclusion of foreign exhibitors on the occasion of the International Foundry Trades Exhibition to be held at the Royal Agricultural Hall, London, from April 24 to May 3, probably the most important of which concerns recent regulations in regard to tariffs. It is this rather than industrial depression that is reflected by the paucity of Continental exhibitors, for it has tended towards production of their specialities in this country by accredited agents. It is noticeable, however, that the Zimmermann machine manufacturing firm, of Dusseldorf, Germany, is one of the exceptions exhibiting.

Considerable development has been made in recent years in the production of castings to meet more exacting



Nos. 2 and 3 August's portable mould driers.



The Armstrong-Whitworth semi-rotary oil-fired melting furnace.

modern conditions. This is due, in no small degree, to the increased attention now given to the quality of raw materials used; particularly is this true in regard to iron castings, and, since special and refined pig irons have played an important part in these developments, it is natural that many successful brands should be on show at this exhibition. Such firms as Sir W. G. Armstrong, Whitworth and Co., Ltd., Barrow Hæmatite Steel Co., Ltd., Bradley and Foster, Ltd., British Pig Irons, Ltd., Colvilles, Ltd., Stewarts and Lloyds, Ltd., and The United Steel Companies, Ltd., will display pig irons of outstanding quality, and their stands will attract all foundrymen visiting this Exhibition. In the majority of instances castings from special pig irons will be exhibited, while the fractures of the metals shown, as well as their chemical analysis, will be available. The "New Process" iron, in various grades, developed by Armstrong, Whitworth's at their Close Works, Gateshead, will be in evidence. The range for grey irons will show fractures of very fine texture claimed to ensure castings of excellent physical characteristics and ease in machining. A range of malleable iron will also be shown which gives castings of low sulphur content, quick annealing time, and high elongation.

The popular brands of hematite pig iron, known as "Barrow" hematite by foundrymen over a period of about 70 years, are still being used in increasing quantities, doubtless due to their unvarying high quality. Supplied to analyses and specifications, many of these brands will be shown. Much interest will be created by a new quality of pig iron introduced by this firm; it is known as "Barrow Phosphoric," and is an all-mine, hot-blast, sand-cast, close-grained tough iron having the following composition:—Total Carbon, 3·50 to 3·75%; silicon, 1·5 to 4·0%, as required; sulphur, 0·04% maximum; phosphorus, 0·10 to 0·50% in 0·05% limits; manganese, up to 2·0%, as required. Probably the most interesting of the exhibits of Barrow Hæmatite Company will be "B.H.R." superheated refined iron, which has been developed with a view to assisting in the economic production of high-grade castings. This material is available with total carbon content as low as 2·0%, with sulphur 0·04% maximum and phosphorus varied from 0·04% to as high as required.

A new development by Bradley and Foster, Ltd., will be displayed. This consists of a range of hard, white, and soft grey heat-resisting chromium alloy pig irons, which are particularly economical for such castings as firebars, furnace parts, annealing boxes, and similar castings required to give long service in the presence of heat. The harder grades in this series are also useful for many of the cheaper types of castings that need hard chilled surfaces to resist wear. Fractured specimens of the wide range of refined and refined alloy pig irons and ingots manufactured by Bradley's will be on view, including refined malleable and cylinder irons, alloy pig irons containing chromium, nickel-chromium, vanadium-titanium, molybdenum, and molybdenum-chromium. In addition, special refined pig irons, such as "Silal," "Nicrosilal," and "Nimol," will also be included in these interesting exhibits.

The well-known brands of pig iron manufactured by Colvilles, Ltd., will form an attractive exhibit. Such brands as Dalzell, Glengarnock, Clyde, and Monkland foundry qualities of pig iron; Clyde Special, Ordinary Hæmatite, and Dalzell Special Refined, will be shown as fractures, also in the form of pigs as cast. Several specimens of castings made from mixtures of Dalzell special refined and Dalzell No. 4 Close Cylinder qualities will be displayed. The special feature claimed for Dalzell Special Refined is its low total carbon content, this being 3·0% maximum.

Stewarts and Lloyds will have much of interest to the foundryman, for, in addition to samples of foundry, forge, basic, and special pig irons, under the well-known brands of S.V.H., Lloyds and Islip, limestone and ganister will be shown. The latter is Lowick ganister, which is a highly

refractory material milled and supplied ready for use. Of the pig iron the S.V.H. brands are very strong and particularly suited for good quality castings, while the Lloyds and Islip brands are suitable for general engineering castings, particularly light castings.

The remarkable strength and consistency of Workington hematite is generally appreciated ; this forms the basis of a series of " W " brand pig irons manufactured by the Workington Iron and Steel Co., a branch of the United Steel Companies, Ltd. The " W " brand series is specially prepared for the manufacture of strong castings, such as cylinders, rolls, brake drums, Diesel castings, and others, in which strength is necessary under varying conditions of service. The carbon contents of this series—2·40 to 3·08%—is low, and it is important to note that this is not obtained by dilution with steel scrap. Another important feature of this pig iron is the low sulphur content. Fractured specimens of these and other pig irons, together with their analysis, will be shown.

Austenitic nickel cast iron is attracting a considerable amount of attention at the present time on account of its marked degree of resistance to corrosion and heat, and its high electrical resistance coupled with a low temperature coefficient of resistance. Castings chosen to illustrate these qualities will be shown by the Mond Nickel Co., Ltd., while among the heat-treatable irons will be roller-end

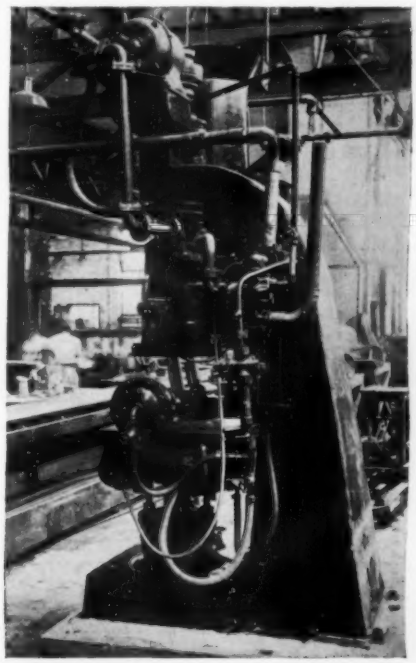
A "Sterling" rolled-steel moulding machine.

castings for wooden textile rollers, the tangs of which have been bent over to indicate the malleability after heat-treatment. Apart from nickel cast iron, castings in nickel alloy steel and in the different non-ferrous alloys of nickel will also be displayed. No visitor who is associated with an iron foundry should fail to get a chart which has been prepared by the research department of the Mond Nickel Co., Ltd. This chart is adjustable and enables analyses to be obtained which are recommended for particular types of work. It is an ingenious device and will prove invaluable to the average foundryman.

The value of sodium carbonate (soda ash) for degasifying and improving the physical properties of cast iron is being increasingly appreciated, and I.C.I. (Alkali), Ltd., will exhibit sodium carbonate in two forms suitable for use in iron foundries—viz., dense sodium carbonate and fused sodium carbonate. The former is used for general castings when the metal is tapped into ladles of about 6 cwt. capacity or upwards, while the fused block are added to the cupola charge where small ladles are used and very hot metal is required. Test bars will show the excellent physical properties of metal treated with sodium carbonate, and a number of specimens will illustrate the powerful effect of this treatment in degasifying the metal and in eliminating segregations of harmful impurities.

Several materials will be exhibited by Robson Refractories, Ltd., notably Cupoline for lining cupolas and various types of furnaces and ladles. Many claims are made for this refractory that foundrymen will find it profitable to investigate. A mould-facing material known as Finitol is another speciality, whilst Fluxitol for increasing the fluidity of iron and steel, Ados for desulphurising the metal, Kerasit for repairing moulds and chills, and core oil, represent a few of the materials exhibited by this firm.

The importance of suitable refractory bricks, cements, sands, and compositions in the foundry cannot be overestimated, and the wide range of these materials displayed by General Refractories, Ltd., will prove attractive. Specimen bricks and shapes will be shown of acid, basic, and neutral character. Mention may be made of a number of types of bricks, especially Silica, Hylumina, Magnesia, Sillimanite, and Diazite, the latter, a new development, being composed of a highly refractory chrome-alumina-magnesia spinel. During recent years this company have added largely to their resources of steel, iron, and brass



No. 3A size Automatic Borrman core-making machine.

moulding sands, and a comprehensive range of samples will be available for inspection. The various grades of Erith loam and Mansfield sand are well known and are admirable for moulding purposes, and samples of these will be shown by J. Parish and Co.

Some examples of melting equipment will be exhibited, and mention may be made of the " Titan " cupola of the Constructional Engineering Co., Ltd., part of a model of which will attract attention. A 3½-cwt., oil-fired, non-crucible, semi-rotary furnace will be exhibited by Sir W. G. Armstrong, Whitworth and Co. (Engineers), Ltd. This furnace will be shown in operaion and attention is particularly directed to the new feature which takes the form of a bottom-pouring valve, which affords many advantages.

A cimprehensive range of furnaces and crucibles will be exhibited by the Morgan Crucible Co., Ltd., which will include a tilting unit for melting pure nickel, Monel metal, alloy cast iron, etc., a bale-out furnace primarily intended for melting and maintaining charges of aluminium and its alloys. Other exhibits by this company, in addition to crucibles, include retorts used for the distillation of zinc from silver-lead-zinc alloy, as well as its volatilisation in the standard process for the production of the high grade zinc oxide.

Foundry equipment in keeping with modern conditions is being displayed by August's, Ltd. Included in their comprehensive range of exhibits are a Simpson intensive sand mixer, an August Borrmann core-making machine, portable mould driers and portable core stoves. One stand will be fitted up as a cinema and films of August's foundry installations will be exhibited at frequent intervals. Many

of the machines shown will be demonstrated and visitors will be able to judge their efficiency and advantages in comparison with other types. Particular attention is directed to the core machine, which is capable of producing cores weighing from 20 to 40 lb., of intricate designs, in a complete production cycle of 10 to 15 secs. per core.

Various types of moulding machines and other special equipment will be shown by Foundry Equipment, Ltd., and the Zimmermann Machine Co., which will attract considerable attention.

The importance of proper fettling equipment cannot be overestimated and the display of Tilghman's Patent Sand Blast Co., Ltd., should be carefully inspected. Grinders, too, are invaluable for the cleaning operations necessary to castings, and the Redman high-speed floor stand grinders, shown by the Carborundum Co., Ltd., will be of special interest. Pneumatic tools will be exhibited by Armstrong, Whitworth, which include their latest rotary air grinders, chippers, sand rammers, etc.

In the modern foundry, where boxes have to be handled rapidly, lightness is of great importance, and as unskilled labour is becoming more and more general, an accurately fitting box is absolutely indispensable. Boxes made from rolled steel strip of special section, and malleable lugs and handles are being shown by Sterling Foundry Specialities, Ltd. The design adopted produces a box that is light to handle, absolutely accurate and interchangeable in use, and which, at the same time, is practically indestructible.

The microscope has now become an essential instrument in the laboratory eqiupment of the modern foundry, and a number of these instruments will be displayed, notably the Vickers projection microscope, which is now made by Messrs. Cooke, Troughton and Simms, Ltd., and the Leitz metallographic microscope. The former instrument is fitted with a comparison screen which enables the user to judge by comparison the effect of various heat-treatments, fatigue, strain, and the equality or inequality of metals against an approved standard. A dark slide is also provided to enable photographs to be taken of the specimen for record purposes. The Leitz metallographic microscope carries a vertical illuminator with glass plate and prism on one spindle, interchangeable with a new dark-ground illuminator, the latest innovation in metallography. The new illuminator shows inclusions clearly, also brings out various constituents in natural colours. The objective stays in focus when changing over from one mode of illumination to the other, and the dark-ground illuminator yields an image free from glare and haziness. The microscope MM with this attachment is a proper polarising microscope for reflected light.

Correspondence

Taxation Relief as a Stimulus to Industry.

The Editor, METALLURGIA.

Sir,—By a provision, in his forthcoming Budget, that for the next three years expenditure on plant, premises, and accessories for the improvement of business should be chargeable against profits for income-tax as to 33⅓% of their original cost, instead of 5% on reducing values, as at present, the Chancellor of the Exchequer would be giving a splendid stimulus to industry and employment, while involving the Treasury in no net loss of revenue. In fact, their figures would show a gain.

This sounds a startling proposal, but let us reduce it to figures: Of each £1 so spent, one-third—6s. 8d.— would be chargeable against the profits of the year, reducing income-tax by 1s. 8d. But every £1 spent in equipment would mean at least 10s. spent in wages; in many cases more. Every 10s. spent in wages would obviate the necessity of spending 3s. 4d. in dole payments (assuming the average wage earned is three times the dole). Therefore a net gain of 1s. 8d. in the £ would result.

Thus, if a firm making £100,000 profits and paying income-tax of £25,000 were encouraged to spend £30,000 on new equipment, they would pay £2,500 less in taxation to the Treasury (*i.e.*, 5s. in the £ on £10,000), but would create £15,000 in wages, and thus obviate the spending by the Treasury of £5,000 in dole, a net gain of £2,500.

In such times as the present a measure of taxation relief calculated to create employment in this manner would seem sound finance and wise statesmanship.—Yours very truly,

(Signed) ARTHUR H. GLEDHILL,
Chairman, Yorkshire Area Institution of Mechanical Engineers.

Trinity Works, Halifax,
March 20, 1933.

Forthcoming Meetings

IRON AND STEEL INSTITUTE.

May 4 and 5. Annual General Meeting at the Institution of Civil Engineers. The following papers will be presented for discussion:—"Coke Consumption in Blast Furnace Practice: Effect of Removal of Breeze," by D. F. Marshall and R. V. Wheeler; "The External Heat Loss of a Blast Furnace," by D. F. Marshall; "Recent Developments in American Blast-furnace Design and Practice," by W. A. Haven; "Structural Changes in Hypo-eutectoid Steels on Heating," by Sir H. C. H. Carpenter, F.R.S., and J. M. Robertson; "Some Comparative Corrosion-fatigue Tests, Employing Two Types of Stressing Action," by H. J. Gough and D. G. Sopwith; "Formation of Columnar Crystals in Steel Sheet after Normalisation," by F. Kinsky; "Contribution to the Study of Inclusions in Steel," by A. M. Portevin and R. Perrin; "First Report of the Steel Castings Research Committee"; "The Influence of Phosphorus on the Properties of Hardened and Tempered Cast Iron," by J. E. Hurst; "The Effect of Sulphur and Phosphorus on the Corrosion of Cast Iron," by L. Tronstad and J. Sejersted; "Internal Combustion Engine Exhaust Valve Failures," by C. C. Hodgson; "A Contribution to the Study of the Properties of Austenitic Steels," by L. B. Pfeil and D. G. Jones; and "The Intergranular Corrosion of the 18/8 Stainless Steels," by E. C. Rollason.

May 4. Annual Dinner of the Iron and Steel Institute in the Grand Hall, Connaught Rooms, Great Queen Street, London, W.C.

THE INSTITUTE OF METALS.

May 10. The Twenty-Third Annual May Lecture to be delivered by Monsieur Albert Portevin (President of the Société des Ingénieurs Civils de France), at the Institution of Mechanical Engineers, Storey's Gate, Westminster, London, S.W. 1, the subject of the Lecture being "Quenching and Tempering Phenomena in Alloys."

THE INSTITUTE OF MARINE ENGINEERS.

April 25. "Some Developments in British Oil Engine Design," by W. S. Burn, M.Sc.

INSTITUTE OF BRITISH FOUNDRYMEN.

NEWCASTLE-ON-TYNE BRANCH.

April 27. Annual General Meeting. Papers by competitors successful in the competition on January 25.

SHEFFIELD BRANCH.

April 21. Annual General Meeting. "The Technical Committee and Technical Developments in the Foundry Trade."

WEST RIDING BRANCH.

April 29. Annual General Meeting.

AMERICAN SOCIETY FOR TESTING MATERIALS.

June 26 to 30. Annual General Meeting at Chicago during the Century of Progress Exposition.

INSTITUTION OF WELDING ENGINEERS.

LONDON SECTION.

April 19. Three Films will be exhibited dealing with "Automatic Metal Arc Welding," "Automatic Flash Butt (Resistance) Welding," and "Oxyacetylene Welding."

MANCHESTER SECTION.

April 19. Annual General Meeting. Film on "Oxyacetylene Welding."

INSTITUTION OF MINING AND METALLURGY.

April 20. General Meeting. "Drill Steels for Mining Purposes," by Dr. W. H. Hatfield.

April 26. Annual Dinner of the Institution.

Some Aspects of the Manufacture of Chilled Iron Rolls

By Archibald Allison

(*J. J. Habershon and Sons, Ltd., Rotherham*).

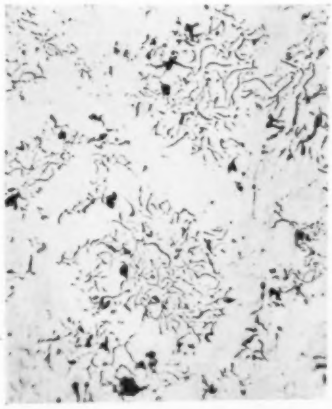
The production of chilled iron rolls demands the careful construction of a system which in many respects is unique. In this article the author discusses some aspects of their production and empasises the need for mutual accommodation and co-operation between producer and user.

THE manufacture of chilled iron rolls has been definitely carried on for 150 years, and it is very remarkable that, originating in South Wales and spreading to the Midlands, the world supply for generations was from Great Britain. The possibility should not be excluded that in various places quiet craftsmen have produced chilled rolls, like other metallurgical products, without leaving any record, and that their art died with them, in this and many other branches.

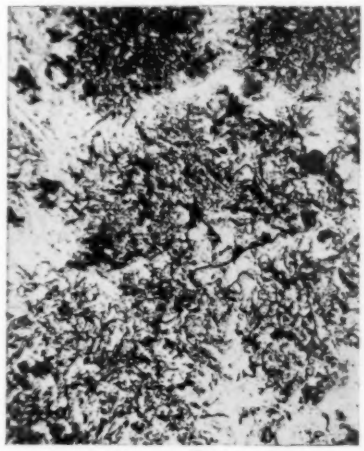
The great firm of Krupps of Essen state that to compete with the chilled iron rolls imported into Germany from Great Britain during the latter part of the eighteenth century, Alfred Krupp in 1818 endeavoured to produce hard steel rolls. This, however, was for cold rolling, and in later years great success was achieved.

The primary use of chilled iron is for hot rolling iron and steel, because it has been found that a better surface is imparted to the rolled product by the resistance of the roll to the indentation of the hard oxide scale which is inevitably present.

A hard and strong grey iron, such as is used for grain rolls, presents a surface which really consists of closely packed rosettes. It is well recognised by micrographers that graphite in cast iron is formed by growth from nuclei, with an almost floral effect in strong, or low-silicon irons. Hence in such irons the flowers, or rosettes, are small and close together, leaving, as it were, cell walls of pearlite to separate them. Fig. 1 illustrates this characteristic structure. The variable hardness of the rosettes and the cell walls enables the scale on the steel in hot rolling to be broken up, which is desirable for some purposes but not for others.



Grey Part of Roll Unetched × 40.



Grey Part Etched × 40.

Fig. 1.—The pearlite between rosettes does not afford photographic contrast.

"Finish" is a very variable requirement. Even at the present time, with the spread of technical knowledge and dispersal of industry throughout the world, as far as rolling mills are concerned, "Sheffield trade" is a specialised branch of rolling both as regards accuracy, appearance, and general condition.

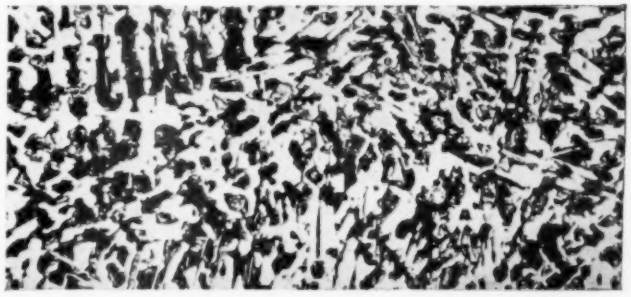


Fig. 2A.—Chill surface × 100 etched with nitric acid, showing the ends of the dendritic crystals. Dark areas pearlite, light areas cementite.

One cannot say that chilled iron presents a homogeneous surface in actuality, when one considers the microstructure, but mechanically the effect upon the scale is equivalent to homogeneity, and for fine finish a chilled roll is essential. Fig. 2 shows the structure presented to the metal to be rolled.

Before leaving this aspect, it may be mentioned that a type of roll, known as bastard, is produced which is most useful for some purposes. This consists of a partly chilling iron cast in a chill, so that the surface layers consist of chill interspersed with extremely fine graphite, hardly visible to the naked eye. This material turns more easily than

Fig. 2B.—Actual chill surface × 200. On etching with sodium picrate to verify the constituents, the carbide in the pearlite is slightly attacked (light areas). The massive carbide is coloured in shades of mauve and green, suggested by varying tones of the photograph. Further etching gave rich shades of orange and green. This effect has been noticed with other high-carbon alloys. Note that the carbide is silico-carbide and the pearlite silico-pearlite, since the metal contains 0.80% silicon, but low-silicon alloys give the same colours.

Fig. 3.—Bastard chill × 200 pearlite, fine graphite and free carbide. When etched with sodium picrate the same beautiful mauve and green colours as above were obtained.

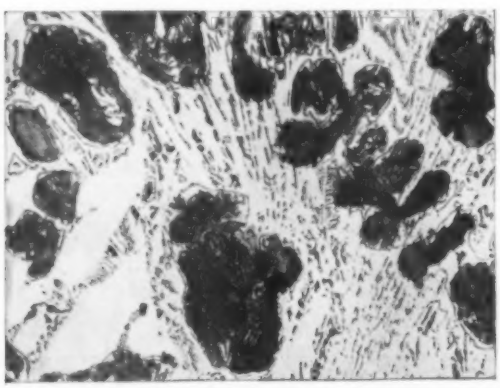
pure chill, gives an excellent surface, and also mechanically strong rolls. Fig. 3 illustrates this material.

The purposes for which chilled rolls are used are extremely varied. Crushing corn, rolling foodstuffs, textiles, rubber sheet, paper, and all metals, are a few processes. One must reserve the possible contingency that some of the softer materials may have peculiar physical properties when in intimate surface contact, and produce difficulties; but if the rolling of steel—surely the most stubborn of plastic materials—be considered, all other purposes will be covered thereby. Probably the most severe demands upon cast iron are the requirements made upon chilled iron rolls for rolling tinplate and steel strip. In the absence of casualties, the rolls in tinplate mills are worn out by 12 to 16 weeks' continuous use. The life is even shorter in steel strip hot rolling, but the rolls are taken out and dressed more frequently.

In the pursuit of economy in different periods, every item of cost is scrutinised, and the roll cost per ton of steel rolled has come under examination, with results which are in a certain sense disappointing. In dealing with steel, for instance, one readily finds in the voluminous technical literature useful information upon most points, but in the published matter upon cast iron, chilled rolls are hardly more than hinted at, prior to the papers by Dr. Schüz in *Stahl und Eisen*, 1923, although it is true that the analysis of a typical chilled roll was given by Prof. Turner in 1887 in discussion at the Iron and Steel Institute.

There are several reasons for this. In the case of most castings it is possible to cut out a test-piece from the body of the article for the purpose of ascertaining its mechanical properties and compliance with specification. This cannot be done with a chilled roll. The machining alone calls for special lathes and tools, and the operation has been rightly described as barbarous. The tool only penetrates the

Fig. 4.—Pellet from cavity in roll barrel. P, 2·73%, analysed after photographing.



material by propulsion with a hammered wedge or strong screw, and it is dubious if the word cutting can be correctly applied to the process. Chemical analysis has only in recent years been seriously applied to cast iron, and even now the information obtained requires careful interpretation.

The principal reason for lack of general knowledge upon chilled rolls is that roll-founding has been, and still is, largely a craft, and the craftsman is inarticulate both by aptitude and desire. The attitude of mystery has also been fostered by the producers of cold blast iron, which is practically the only source of iron so low in silicon as to be within the chilling range.

The social and economic changes which have torn aside the veil of mystery by demanding that an industry should not be dependent upon individuals, however skilful craftsmen they may be, would be a lengthy though interesting study. Suffice it to say, that in other days a productive efficiency of 75% was considered satisfactory. Even to-day 100% of saleable castings of chilled rolls is not within reach, even with the application of such scientific knowledge as we possess, and this application is far from being general. Rolls are made in many parts of the country, with the usual unwritten rule of specialisation in manufacture.

Large foundries sometimes make the whole range of sizes from 10 to 15 tons in weight with barrels maybe 10 ft. long by 3 ft. diameter, down to rolls of a few hundredweights with barrels 9 in. long by 8 in. diameter. Other foundries confine their attention to rolls of 2 to 7 tons weight.

Whilst the metallurgical principles are the same, the technical difficulties vary from the serious responsibility of casting the heavy weights to the awkwardness of obtaining the exact depth of chill on small rolls, and the difficulty of making sound castings of hollow rolls with long necks.

Briefly, it may be stated that the production of chilled iron rolls demands the careful construction of a system which is unique in many respects. The box parts are a normal feature in castings. The chill moulds for the barrel are another matter. A stock of these is required, capable of meeting demands for every conceivable length and diameter of roll barrel. These chills require to be carefully cast from suitable iron, with sufficient discard to leave a perfectly solid body.

The study of ingot moulds is helping to decide the correct metal for chill moulds.

Adequate machinery is requisite for turning and boring these expensive tools, which may or may not last for 40 casts without reboring.

A varied stock of suitable materials must be selected and maintained to meet the melting conditions of the particular furnaces installed. Some kind of hearth furnace is essential for the production of rolls of heavy weight, and in this connection there is decided promise in the development of pulverised coal or oil fuel applied to rotary or tilting furnaces, both on grounds of convenience and economy.

At the same time, since the head of the rolls after casting requires to be fed with molten iron to avoid contraction cavities, a cupola must supply this metal, and this demands the production of ordinary iron castings, because the cupola is a continuous furnace, and feeding rolls take only a small part of the cupola output. Cranes and ladles may be taken as normal to any foundry, but the machinery for turning the cast rolls, for proving, or finishing, and possibly grinding, is of a special and expensive character.

The personnel is probably a more difficult matter still. The moulding and preparation of the mould require very careful work and unfailing diligence, but it is in connection with the supply of metal that the principal difficulties are realised. The target aimed at is the obtaining in the ladle of adequate, but not too much molten iron at a suitable temperature, and which will throw the desired depth of chill on the cast roll. In the past the craftsman has mixed irons by judgment and—all credit to him—has obtained excellent results.

Thoughtful observers have commented on the solemn ritual of making the chill test, but after making over five thousand such tests, the writer feels that neither the ritual nor the care can be diminished without risk: there is little or no margin for inaccuracy.

Modern productive methods demand adherence to time schedule, and charging the mixture by chemical analysis is one essential for this. It must be remembered that with some melting systems, if the metal is not right, correction is difficult, and may mean putting the iron into pigs and postponing the casting till next day.

The limits of economics prevent the construction of an adequate electric furnace for melting, say, 15 tons of iron without serious loss by oxidation—a consummation devoutly to be wished. Therefore the iron must be melted in such furnaces as are available, and the resultant effect of all the losses by oxidation measured by chill test, because not only are the materials variable in composition, but also the oxidation of the elements is variable.

The pulverised coal or oil furnace offers the possibility of maintaining the heat of the metal indefinitely, with consequent facilities for correction. If the iron is short of chill, material to produce chill can be added and dissolved in the molten bath. When chill is too deep on the trial piece, correction is easy by adding grey iron melted in the cupola. By similar means to these, chilled rolls are cast from synthetic mixtures of roll scrap, pig iron of various kinds, and steel scrap. It is also possible to sample and analyse while the metal is still in the furnace. In this way the total carbon is definitely under control, which is of importance according to the class of roll being produced. The possibility is also indicated, under certain circumstances, of the use of ferro-silicon or nickel shot to reduce chill, and chromium alloys to increase chill, with a view to speed of operation.

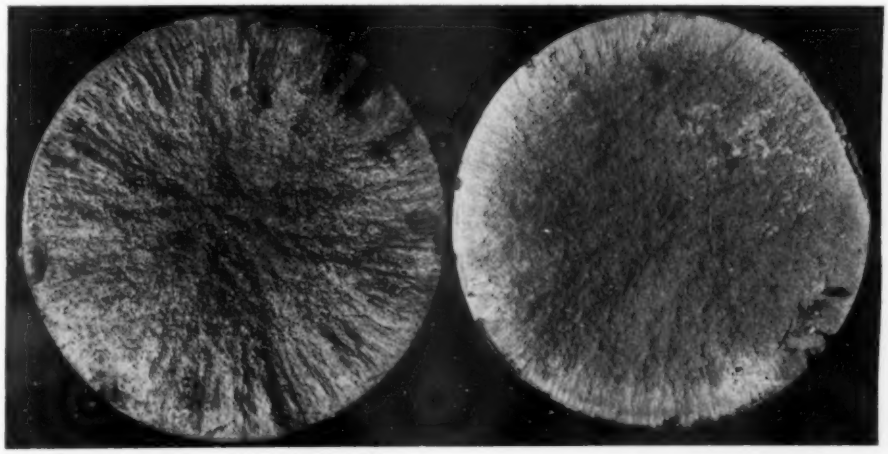


Fig. 5.—Showing fracture of a roll that failed after a few weeks' life. Note the dendritic structure persisted almost to the centre.

Fig. 6.—Shows a roll with chill slightly deep and a perfectly grey body of excellent texture.

About One-Sixth Actual Size.

A necessary part of the system, therefore, is a laboratory and some metallurgical personnel, unless the foreman has sufficient metallurgical knowledge, and close co-operation between these two branches is essential. In a sense there is a need for craftsmanship of control as well as of the moulder, because the cooling of the test-piece and appropriate action consequent upon measurement of the fracture call for prompt and accurate decision upon which so much depends.

The decision must be influenced by knowledge of the carbon contents, possible chromium contents, and relation of the chill depth to size of roll being cast. Careful observation of the casting temperature with a pyrometer is to be made and noted, and finally the roll turner's report of the chill and characteristics of the roll, for comparison with the customers' views, are all to be filed in the records as part of the system.

The casting is either good or bad—repairs are out of the question. This particular production, therefore, demands the erection of a system with unusual features, and in which the human factor is to a certain extent irreplaceable.

The user or mill manager being in the position of purchaser, is frequently perplexed or exasperated by the behaviour of chilled iron rolls. These expensive tools, after careful turning, break unexpectedly after a very short life, and no evidence is available to indicate the cause of failure. On broad lines, the following points collected from various sources may be of some value. External examination may reveal improperly fitted coupling boxes, excessive backlash, or other unsuitable mill fitting. The surface of the barrel may be coloured deep blue in one part, indicating a severe temperature gradient. The fracture itself may be coloured progressively from the outside towards the centre, showing that cracking has occurred previously through some mishap unnoticed or unrecorded.

If the depth of chill is reasonably correct and the centre definitely grey, nothing can be said about the metal, but if the chill is uncertain and deep, with mottle extending right to the centre, then the roll is at fault. Such rolls do give a fair life, but are liable to fail, and it must be pointed out that to satisfy some requirements is extremely difficult. Rolls of 12 in. diameter or less, and with barrels two and a half or three times the diameter, are particularly difficult to make when a chill of $1\frac{1}{2}$ in. is demanded. The roll appears to be chilled right through, or not deep enough in chill almost by caprice. This opens up the question whether or not some mills are doing work beyond their capacity, because if the section demands deep chill then a larger diameter roll is indicated as desirable.

Ideally and essentially, of course, a chilled iron roll consists of a grey iron body with a hard surface layer, but it is necessary to have a greater depth than this to provide for wear and dressing. Therefore, as in all considerations affecting cast iron, compromise is necessary. The aims should be, as regards chill depth, the minimum required to give a fair amount of material for redressing. If a greater depth is insisted upon, the responsibility for service cannot rest upon the founder.

Roll users naturally wish to purchase chilled iron rolls on the basis of specification and test, in the same way that other engineering commodities are obtained. It is, however, quite impossible to make mechanical tests upon chilled iron rolls because a test-piece cannot be excised. What tests can be made, therefore? For chemical analysis the thin needle-like slivers produced in turning the barrel provide an ideal sample. The Brinell test is unsuitable, because the article is too massive to be placed under the machine, and, further, the depression produced must be removed by machining the entire surface area. The scleroscope test is easy, leaves no deep mark, and affords useful information about the character of the chill.

As far as the severe uses of chilled rolls are concerned for the hot rolling of thin steel, it has been found that a low total carbon, 3·1% or less, gives longer life and freedom from surface cracking. This is accompanied by a scleroscope test figure as low as 55 for tin-plate rolls with carbon 2·9%. Another feature of low-carbon rolls is the uncertainty of deciding upon the exact depth of chill, the transition from chill to grey being very gradual.

Higher carbon rolls are made and used for the less severe

demands (Mort, *J.I.S.I.*, 1930) of cold rolling other materials as well as steel, and with a total carbon content of 3·3% a scleroscope figure of 72 or higher may be reached. All these figures are variable according to the mass annealing produced by increased diameter, and also the effect of the coating on the chill mould acting as insulation between the mould and the casting.

As far as other elements are concerned, in Great Britain manganese is usually little more than sufficient to balance the sulphur in chemical ratio, although higher manganese rolls are made on the Continent. Phosphorus up to 0·65% appears to have no detrimental effect, and undoubtedly assists casting.

Occasionally a roll when stripped from the mould is found to have a split of moderate dimensions at the bottom end of the barrel. This is apparently caused by sticking to the chill mould, although evidence is sometimes absent. A moderate split can frequently be remedied by turning, although a line of different colour is sometimes perceptible. The argument is that the chill has ruptured shortly after casting under the influence of some peripheral tension, but that the root of the crack is welded by liquated phosphides squeezed out by the dendritic crystals. If that be the case, then any gas cavities or similar irregularities may similarly be welded up or autogeneously repaired by phosphide liquations. Evidence of this is afforded by Fig. 4. This represents the structure of pellets such as are often found in cavities in the end of the barrel of a roll cast too cold. Such pellets frequently contain 3% phosphorus, although the roll metal contains less than 0·5%. In a similar manner, the surface of a perfectly sound roll may have fine excrescences of phosphide ejected between the dendrites of the solidifying chill crust, and forming bristles. These also have been found to contain 3% of phosphorus.

This phenomenon has an important bearing upon the solidification of ingots of any heterogeneous metal, because in the case of steel ingots for example, phosphides and other liquations are ejected internally from the dendritic crystals into any cavities which may be present.

As far as sulphur is concerned there is every reason for thinking that in iron of chilling quality the presence of sufficient manganese to form MnS stabilises the sulphur into harmless inclusions, so that a sulphur content of 0·18% has not prevented rolls from rendering excellent service.

Alloying elements must be used with caution, because the iron is already nearly a saturated solution, and it has yet to be proved on a bulk scale that alloys beyond 0·5% chromium seriously improve the durability of chilled rolls, although there is evidence of greater mechanical strength in alloy rolls. The addition of alloys increases the difficulty of obtaining exact chill, and failures are extremely costly. Many rolls are now in use containing nickel, chromium, and molybdenum, and when worn out the comparative life and cost will be ascertained.

To illustrate the difficulties associated with production, the following examples may be cited :—

Fig. 5 is the fracture of a roll which failed after a few weeks' life. Although the true chill was only slightly deep, the dendritic structure persisted almost to the centre, which was not entirely grey, and hence the roll was not good enough.

Fig. 6 shows a roll with chill only slightly deep for the purpose intended, and with a perfectly grey body of excellent texture. In this case, therefore, the roll had failed through thermal or mechanical irregularity in the mill.

The thermal constants of cast iron do not vary much from the grey to the chill, but the latter is more sensitive to heat because of its greater rigidity. Hence it is gradually coming to be acknowledged that chilled rolls break mostly through irregular temperature conditions.

When no definite test can be made upon any product, only deductions from results in bulk can be used.

It has been definitely established that chilled rolls are better for keeping in store for six months before use.* The theory is that by fluctuations of temperature over a period of time, the natural casting stresses have been relieved. As far as possible for standard requirements a pool of rolls dressed for use or in process of redressing would appear to make for economy. It has also been found economical to employ some form of heater to prepare the roll for some hours before use and to maintain the heat during stoppages, and electric heaters are now made and applied for this purpose.

Since there is abundant evidence that chilled rolls are very sensitive tools, and that extreme demands are made upon the intrinsic properties of the metal, it may be asked, "What can be done to obtain more efficient use ? "

The answer to this question must be found in co-operation between the founder and the user. Time is an important factor. There is a decided advantage in rolls being allowed to cool in the pit, and not stripped for some days, and therefore only exceptional circumstances should call for immediate delivery of ordered rolls.

Agreement should be reached between buyer and maker, upon the optimum depth of chill, and method of measuring it. Discussion should be encouraged with a view to arriving at standard sizes of barrels and necks and shapes of tenons, because a roll too deep in chill for one mill may be right for another, and vice versa. Failures in service should be thoroughly investigated, and the evidence frankly admitted.

Since the effective saleable production, including replacements and allowances called for, is considerably below actual output, and the purchaser must pay all these charges—otherwise the founder would be forced out of business,—economy and reduction of price can only be effected by mutual accommodation and co-operation between the producer and user of such awkward and sensitive tools, as chilled iron rolls are now recognised to be.

* Bacon and Caswell. Proceedings, S. Wales Institute of Engineers, 1931.

A.S.T.M. Grey Iron Casting Specifications.

At a recent meeting of the American Society for Testing Materials, held in New York City, the adoption of the Tentative Specifications for Grey Iron Castings (A 48–32 T) was recommended as standard. It will be recalled that these specifications were formulated by Committee A–3 with the co-operation of the Grey Iron Institute, and were approved for publication as tentative at the June, 1932, meeting of the Society. These specifications, which include classifications ranging from 20,000 lb. to 60,000 lb. per sq. in. tensile were drawn up to supersede all individual specifications previously existing. The introduction of the specifications as tentative has already removed an element of uncertainty in buying and selling castings, and the specifications have been well received by the industry during the past year. Once they have been adopted as standard, it is expected their value to the industry will be still further increased

The Committee is continuing its work on the determination of value of additional test-bars and the method of making the bar. In connection with the impact testing of cast iron, this Committee has conducted a very extensive investigation on impact testing of cast iron for the last three years. Based upon a careful appraisal of the comprehensive data available, a report on this subject will be presented at the annual meeting of the Society in June.

The Committee on Cast Iron is co-operating in preparing for a Joint Symposium on Cast Iron, sponsored by the American Foundrymen's Association and the Society, which will be held at the annual meeting of the A.S.T.M. in June, at Chicago. The American Foundrymen's Association and the Society are also co-operating in the holding of a Joint Symposium on Specifications and Testing of Cast Iron, which will be held at the 1933 A.F.A. meeting in Chicago.

High Duty Brass and Bronze Castings

By J. Arnott, F.I.C.

The types of casting coming within the scope of this article are mostlv those calling for either high strength or resistance to some form of wear.

THE term high-duty castings could of course also cover those subjected to high temperature or to highly corrosive conditions. These will not be dealt with here, since the alloys most suitable for withstanding these conditions do not come within the brass and bronze group.

Castings calling for high strength and resistance to various types of wear are mainly used in power production and utilisation, or in the heavy industries. Some of the problems involved are not new, though many have been intensified in recent years, while developments in other fields of metallurgy—*e.g.*, in the special steels—have resulted in new demands on the brass foundry.

In general, where non-ferrous castings are required, and where the stresses are under 12 tons per sq. in., they are made in gunmetal or phosphor bronze containing somewhere around 10% of tin.

When we come to higher stresses, especially in the cylindrical and casing types of castings, we reach a point where gunmetal becomes unsuitable. In thick sections in a sand casting the strength falls away, and if allowance be made for this in designing the casting requires to be very heavy for its duty.

In such cases the high strength obtainable in the special brasses allows designs to be kept down to reasonable thicknesses. These alloys are essentially 60/40 copper-zinc alloys with additions of iron, manganese, and aluminium and frequently also tin and nickel. A typical composition when high yield-point and tensile strength are required is :—

		%
Copper	approximately	58
Zinc	„	37
Iron	„	1·5
Aluminium	„	1·5
Manganese	„	2·0

Pieces cut from heavy castings in such a composition can be depended on to give :—

Yield-point	over	16	tons per sq. in.
Tensile strength	„	32	„ „
Elongation	„	20%	

With care, higher figures can be obtained from actual castings, and separately cast test-bars will give 38—43 tons per sq. in. Where a lower yield-point and higher elongation are desired, smaller amounts of the hardening elements may be employed.

It is common to leave the composition entirely in the hands of the supplier, or only to limit certain of the elements. The Admiralty only limit the iron and manganese and call for a tensile strength of 33 tons per sq. in. and an elongation of 15%.

The production of special brasses calls for care in two directions—viz., adequate provision for the high shrinkage of the metal and precautions to prevent dross entering the mould or forming during the actual running. The use of a bottom-pouring ladle, as employed in steel practice, has proved an excellent means of ensuring the cleanness of the metal stream.

One great advantage of the special brasses over gunmetal and phosphor bronze is the clean skin which they give, and the absence of any tendency to penetrate the mould surface. In castings with internal surfaces, which are scarcely accessible and difficult to machine, the smooth surface of the high-tension brasses is a most important point. The two illustrations are good examples of this.

Fig. 1.—Rotary pump casing in high-tension brass.

Fig. 1 is a rotary pump casing, where the volute is impracticable to machine. Fig. 2 is a casting which forms part of a hydraulic transmission gear, in which smooth internal surfaces are absolutely necessary. These two are examples of very highly stressed castings, which must possess a very clean skin and accuracy in size and shape, as well as high physical properties.

The provision of metals which will run together satisfactorily presents much more difficult problems than the simple demand for high strength. For one thing, it is not easy to make any laboratory tests which will be a guide to the performance of a machine in service, since the variables met with in practice are load, speed, lubrication, shock, and temperature.

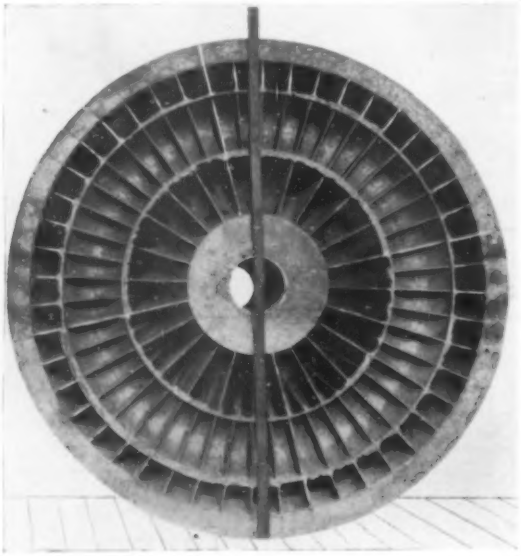
It will be noted that frequent reference is made to hardness. One of the outstanding advances in the non-ferrous world in recent years is the development of alloys of greater hardness than the ordinary bronzes. The gunmetals and phosphor bronzes all come within the range of 60–120 Brinell. To-day we have several series of cast alloys, giving over 200 Brinell, and at least one group which has a hardness exceeding 300 Brinell in the cast state without heat-treatment. This wide range of available alloys has enabled many of the difficult wear problems to be solved. It is not suggested that hardness is the only factor in consideration of the suitability of an alloy for a certain purpose, but experience indicates that within any one group or family there is a very definite relation between hardness and wear resistance.

In the course of the following remarks, a rough classification of types of severe service conditions will be made on the basis of the type of motion present.

1. *Rotary Motion. Heavy Load.*—Rolling-mill bearings may be taken as typical of excessively high load, moderate surface speed, shock, temperatures above normal, and intermittent lubrication contaminated by grit and mill scale. In many mills the conditions are so severe that even

the best bearings which can be produced have a life of only days, or at most weeks. But even in these extreme conditions, considerable improvements in bearings have been effected. A lead content of 5 to 12% is necessary to give the plasticity to accommodate for poor lining-up and varying shapes of roll neck. To counteract the weakening effect of the lead and ensure its even distribution, the addition of small percentages of nickel of the order of 1 or 2% has been a pronounced benefit. The nickel additions confer a greater toughness, which is very acceptable, especially in heavy cogging mills, where the bearings suffer from shock. A further improvement has been effected in bearings for cold rolling mills, by chilling of the faces and necks of the bearings.

2. *Rotary Motion. High Speed.*—Packing rings and thrust collars of centrifugal pumps are instances of light loading with very high surface speed, in absence of lubrication. When unsuitable metals are used, tearing and seizure, which is virtually a local welding of the two surfaces, can take place to an amazing extent, even in presence of cold water. When impellers are of austenitic stainless steel or Monel metal, the question of the packing



By courtesy of Wm. McPhail & Sons.

Fig. 2.—High-tension brass unifiller for hydraulic transmission gear. Dia. 5 ft. 9 in. Weight 1 ton 8 cwt.

rings becomes acute, because these metals, which are both structurally single solutions, are not the most desirable from the point of view of rubbing contact. The ordinary bearing bronzes are not satisfactory, but fortunately the development of nickel bronzes has provided the solution to most of the problems. The most suitable alloys for these packing rings have a hardness of over 200 Brinell, obtained in bronzes of 20 to 30% nickel, with tin contents ranging between 8 and 12%.

In special cases lead additions of 5 to 10% are a further aid. These leaded nickel bronzes are the best alloys now available for some of the most extreme conditions, and represent a big advance on what was possible, say, 10 years ago. It might be added that nickel bronzes have been found successful in bearings working in conjunction with nitrided steel. In these bearings a low percentage of nickel, about 5%, is used, along with 12% of tin.

The manufacture of nickel bronzes calls for some skill in the foundry, since technically they lie between the ordinary bronzes and the high nickel alloys. It is essential to de-oxidise the copper + nickel before adding the tin and lead (if any). If the nickel content is too high for the alloy to respond to phosphorus, recourse must be had to de-oxidation with magnesium, as is usual for high nickel alloys.

Rolling and Sliding Friction.—Under this heading come all types of worm and gear-wheels. In this field there has been very little change in the materials used. The bulk of gear blank castings are made in phosphor bronze, the only alternative of importance being aluminium bronze. The main advance in recent years has been one connected with the method of production—viz., the centrifugal casting process. The process itself and the properties of the resulting gear blanks have been very well described, notably by Mr. F. W. Rowe, hence no further mention is needed here.

In steel works plant, certain thrust collars and bearing blocks are subjected to very heavy sliding friction, and the wear of phosphor bronze castings is rapid. In these particular parts striking success in practice has been obtained from a complex copper-nickel-aluminium-iron alloy. This alloy gives a Brinell of 250, with a high yield-point in compression. Although the ductility is not very high, yet it is sufficient for the parts concerned.

This type of alloy presents difficulties in the foundry. It has a high shrinkage, and is sluggish in pouring, but when the technique is mastered the castings give a remarkably long life under peculiarly arduous conditions.

Reciprocating Motion. Medium and High Speed.—In this group come pump liners, buckets, and rings, hydraulic rams and slide valves. These components have to work in conjunction with cast iron, bronze, stainless steel, and non-metallic materials, such as leather washers and ebonite rings.

The general guiding principle is that where the bronze part is rubbing on cast iron a lead-less alloy is suitable, but in the majority of the other cases a leaded alloy is best. Once the lead content is settled, the next point is to fix the hardness desired. The limiting factor then is the degree of ductility necessary. For liners and parts which are fully supported, very little ductility is required. As a means of obtaining hardness, nickel is again the most suitable addition element. Each 5% of nickel increases the Brinell figure by 30 to 40 points. Nickel also increases the price, unfortunately. Each 5% adds roughly £10 per ton, hence at 20% nickel the actual metal cost is doubled.

For many purposes an alloy of—

	%
Copper	80
Tin	10
Nickel	10

is a composition which shows a great improvement over ordinary bronze, without too great an increase in the final cost of the castings.

Reciprocating Motion. Slow Speed.—In the control of water and steam there are many components, such as sleeves for valves and pressure governors, and facings for straight-through valves, where the main consideration, apart from reasonable corrosion resistance, is sheer hardness. In these parts the relative motion is small; in fact, there may be no movement for long periods. The surfaces are required to withstand the erosive action of the fluid, which, in the case of water, may carry grit along with it.

The metals which are used successfully for this type of service have a Brinell of 240 and over. This is obtained from alloys of the type—

	%
Copper	60
Nickel	30
Tin	10

or, alternatively, from the copper-nickel-aluminium series previously mentioned.

These remarks may serve to indicate how the range of brasses and bronzes has been, and is being, extended to meet the demands for higher loads, speeds, and efficiencies. In point of tonnage, the greatest proportion of brass foundry outputs still consist of ordinary gunmetal, and it is probable that such will long continue to be the case.

The cases which have been cited are those of castings which may be relatively insignificant as far as weight is concerned, but which are of vital importance to the machine or structure of which they are a part.

Some Observations of Automatic Temperature Control

By C. E. Foster, F.Inst.P.

The automatic control of high temperature processes covers now a very wide and rapidly growing field, and the services which it can and does perform in the way of improved product and bigger output are so important that no excuse is needed for study and discussion of some of the details of the installation. It is intended here to consider only the system of automatic control which operates primarily by the indications of an electrical pyrometer.

THE designer of the instrumental part of the equipment is naturally, and often rightly, enthusiastic as to the accuracy and closeness of the limits within which it operates. The prospective user catches this enthusiasm, and is, on his part, quite justly sanguine as to the possible advantages in his manufacturing process, with the result that, sometimes, insufficient attention is paid to the whole installation, and the hoped-for results are not realised in the first instance. The instrument maker may have been unaware of factors outside his apparatus which might operate against its efficient use, the prospective user is often, naturally, ignorant on the matter, and "the wish being father to the thought," if "hope told a flattering tale," the plant was put in without further consideration.

The purpose of these remarks is to show that a "reach-me-down" control pyrometer, fitted to a furnace not specially designed for automatic control, may not be a successful installation; further study of the conditions is essential to ensure success. Before it is possible to envisage completely what the automatic control gear will have to do, it is necessary to consider briefly the component parts of that gear and their interaction. As a very simple example, the arrangement shown diagrammatically in Fig. 1 may be taken and the chain or sequence of events may be followed out. We have, in this case, the furnace F, whose internal working zone Z is to be controlled at, or as near as possible to, a selected temperature. The furnace is heated by a natural draught gas burner B. The heat-sensitive part of the control gear is a thermo-couple T, which may be surrounded and protected by a sheath S, such a sheath being almost invariably essential if it is proposed to control at relatively high temperatures.

The thermo-couple T is connected to a pyrometer indicator I of the usual edgewise form, in which the pointer moves over a scale and indicates the temperature experienced by the heat-sensitive junction of the thermo-couple. So far the control gear is identical with the apparatus used simply to give a plain indication of temperature. The indicator is, however, in this case fitted with some automatic mechanism (usually operated by an electrical supply from the mains M), and arranged to close one or more electrical relay circuits.

In the arrangement shown in the diagram there is, from the relay in the indicator, an electrical circuit to the valve mechanism V, whereby the valve is closed a certain amount whenever the temperature exceeds a certain predetermined limit, thus reducing the heat supply and allowing the furnace temperature again to fall to the required figure. Such a layout is actually used in some cases, and furnishes perhaps the simplest example of an automatic control equipment. We may now consider how this acts in service. Temperature change takes place in the zone Z, and this change has then to produce an effect successively through a technical chain.

(*a*) The change in temperature has to penetrate the sheath S and to reach the heat-sensitive junction of the thermo-couple T.

(*b*) The change in the current generated by the thermo-couple has then to produce a change in the reading of the pointer in the indicator I.

(*c*) The relay mechanism in the indicator has next to operate the relay and to energise the valve V so as to reduce the gas supply.

(*d*) The reduced supply of gas has to allow the temperature of the zone Z to fall.

(*e*) Lastly, this fall in temperature has to penetrate to the sheath and reach the heat-sensitive device and so on round the chain again.

A glance at this sequence of events will show that only some of them are within the control of the instrument maker. He can, if the furnace allows it, advise a suitable position for the installation of the thermo-couple, so that, through its sheath, it will quickly "become aware of" a temperature change. From here to the point of closing the circuit from the relay to the valve is clearly the instrument maker's province and responsibility. He may also advise upon or actually supply the valve or other device of ultimate control, but the last link in the chain, the response of the furnace to a change in the supply of heat, is entirely beyond his control, and if the apparatus is applied to a furnace which was not primarily designed for automatic control, this last time lag may have considerable effect upon the closeness within which the temperature control is possible.

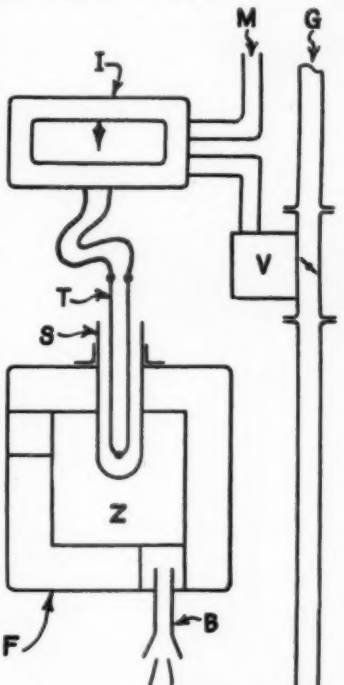


Fig. 1.—Diagram of component parts of automatic temperature control system.

It should be pointed out here that there already exist some special designs of furnace (notably electric furnaces) in which arrangements are made particularly directed to producing a quick temperature response, and it is not surprising that, in such specially designed furnaces, the effective control can be carried to within such close limits that a temperature record on a pyrometer recorder is almost indistinguishable from a straight line. But there are a large number of cases where the furnace design does not at all approach such an ideal condition, yet it is not unusual to find unqualified claims made by over-enthusiastic or inexperienced instrument manufacturers that they can control within such and such close limits No such claim can be made justly until all the factors are accurately known, and therefore, as is usually found with sweeping

statements on technical matters, they are untrue unless carefully qualified. In case it should be inferred from the foregoing and succeeding remarks that automatic temperature control cannot, after all, do such wonderful things, it may be mentioned that a relatively crude form of oil-fired furnace has been actually controlled at 700° C., so that a tell-tale pyrometer embedded amongst the material under treatment in that furnace showed that the temperature did not vary more than plus or minus 3° from the desired figure.

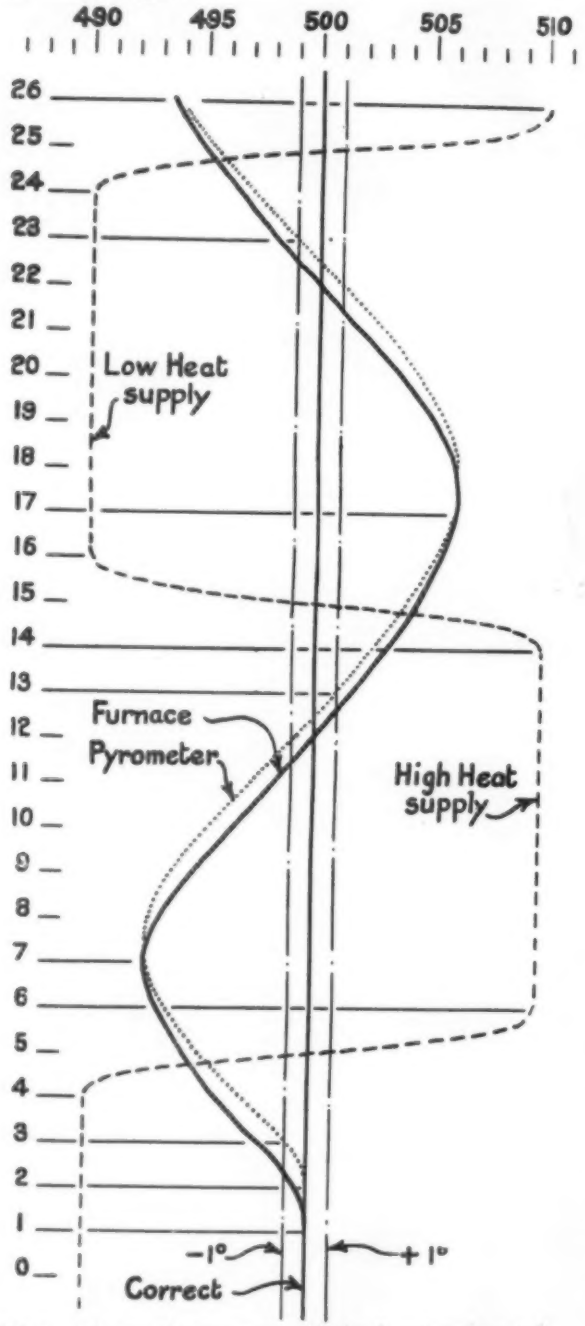


Fig. 2.—Diagram of temperature oscillation in automatic control

The effect of this chain of time lags can best be realised by a diagram. In Fig 2 a time-temperature graph is shown which is arranged in the manner usual in continuous chart recorders, the earlier times being at the bottom and the later times at the top, while low temperatures are to the left and high temperatures to the right.

Let us take again the fairly simple example of a kind which actually occurs in industrial practice, a furnace fired by gas under natural draught, so that it induces its own supply of air, and only the supply of gas needs to be automatically regulated In such a furnace, by means of a prearranged valve setting, there is a minimum supply of gas which, if that only were left on continuously, would result in a steady temperature somewhat below that at which it is desired to control. There is then an additional supply which is automatically controlled by the pyrometer, which adds further gas, so that if this also were left on continuously it would result in a steady temperature somewhat above that at which it is desired to control. These two limits are shown in the diagram by lines of dashes.

Let it be assumed for the moment that the temperature in the furnace was at the desired figure although the heat supply was at the low limit. In practice, of course, this would only result if the temperature were already descending from a higher figure. We can now follow out what happens, dividing time into equal intervals—say, for instance, 10 secs. At time 0 the temperature is at the desired figure. At time 1, for some reason, the temperature tends to fall, as, for instance, putting cold material in the furnace. The fall in the furnace temperature has to be transmitted through the pyrometer sheath (if a sheath is used) to the heat-sensitive part, and thence to the measuring or indicating part of the pyrometer. At time 2 this measuring part of the pyrometer has " become aware " of this fall of furnace temperature.

Every automatic control system has some minute amount of " dead space " within which the temperature may change without the control " doing anything about it." In good designs this dead space is extremely small, and in the case in question it has been assumed at plus or minus 1°. We have to wait, therefore, until time 3, when the temperature as experienced by the pyrometer has passed outside the dead space and the automatic control may then begin to work. There will, inevitably, be some small time lag from this point to time 4, when the heat supply to the furnace begins to increase. We will assume that this is a fairly prompt action, and that the increase in the supply of heat to the high maximum is complete by time 6.

Now this extra supply of heat has to raise the furnace temperature, and we will assume here a very prompt response, so that by time 7 the furnace temperature has begun to turn round again from falling to rising. The pyrometer, of course, will experience a temperature which lags slightly behind in this turning round. We have now the condition that the furnace temperature is rising, and this will continue until the pyrometer reading has passed up to the correct temperature and beyond it to the upper limit of the dead space at time 13. We then have the reverse actions taking place. At time 14 the automatic control gear begins to reduce the heat supply, and this change is completed by time 16.

At time 17 the temperature of the furnace, which was rising, turns round again and, as before, the pyrometer lags slightly behind in this turning round. The process of oscillation will then be regularly repeated. It is worthy of remark that the repetition of oscillation is extremely regular in well-designed and properly installed automatic control systems.

Now let us see how this process affects the closeness of control. We have presupposed an automatic control pyrometer with very small dead space, as to which the enthusiastic advocate might say that it controls within plus or minus 1° at 500°—that is, within plus or minus 0·2%. But even assuming the promptitude in our diagram, we see that the actual oscillation of furnace temperature has been of the order of plus or minus 6° or 7°, and obviously a large part of the time lag which caused this larger oscillation was entirely beyond the control of the maker of the pyrometer : it depended upon the furnace.

In practical work there are two factors which help us to get closer results than this diagram would suggest :—

Firstly, there is in many furnaces an inherent tendency to " steady out "; a fall of temperature which is rapid at first becomes less rapid after a time, and similarly with a rise. This tendency has been indicated in the curves shown

in the diagram, but it is, fortunately, more prominent in several types of industrial furnaces. Secondly, we have the fact that the material under treatment, if of relatively large bulk and heat capacity, does not experience the extreme oscillation of the furnace temperature itself. Nevertheless, the diagram will sufficiently illustrate the point that the accuracy and closeness of control of the pyrometer gear itself, while essential to an ultimate success, is powerless to achieve that success unless the furnace is made accurate and prompt in its response to the changes in the supply of heat.

The type of control shown in Fig. 1 is what is known as the "hit-or-miss," because, within predetermined limits the heat supply is quickly changed from low to high or vice versa. An alternative arrangement will naturally suggest itself—namely, that the supply of heat should change slowly and gradually on the step-by-step system. Space does not allow a close investigation of the probable effect of this alteration of control, but, briefly, it may be stated that with the step-by-step system on a furnace which can lose or gain heat quickly, it results in a larger amount of hunting or oscillation. It is easy to see how this occurs, for, considering the fall of temperature shown in the beginning of the graph, the heat supply will have been gradually increased by successive steps, and this increasing will persist until time 13, when the pyrometer has "become aware" that the temperature has passed above the desired figure. At this instant the increase of heat supply will have reached a maximum, and will then have to be reduced step by step, so that the time when the furnace temperature will turn round again and fall is delayed. In theory, if there were no inherent steadying effect in the furnace, it can be shown that the amplitude of hunting and oscillation of temperature would continually increase.

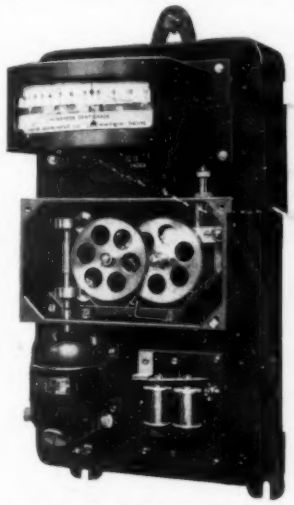


Fig 3.—Typical indicating pyrometer for automatic control.

In practice, it is found that the hit-or-miss system is the better on furnaces which, by virtue of their small size or other factors, can change temperature quickly, while on very large units, in which there is a large "flywheel effect," the step-by-step system may prove the better choice. This is rather a parallel to the experience with the governors of gas engines, in which on the small sizes a hit-or-miss governor works best, whereas on the very large ones the step-by-step system is preferable.

Before considering again in detail the chain of time lags and what we are to do to reduce this as much as possible, it may help the understanding of the matter to illustrate how the pyrometer portion works. For this purpose Fig. 3 is chosen particularly because it is typical of the general system most widely used, but does not illustrate in detail any actual example now in production; it is an obsolete pattern. In this apparatus there is the pyrometer indicator, which, so far as it simply measures the temperature, is like a simple indicating instrument. Inside the case of the indicator is a presser-bar, which is periodically allowed to depress the indicator pointer by means of the motor shown and the reduction gear connected therewith. When the pointer is depressed at a temperature above the desired figure, it closes the primary of a relay shown at the bottom of the panel, and this in turn completes the circuit to the valve or other gear to reduce the heat. The motor is arranged to give very frequent depressions, so that the instrumental response is rapid and the time lag here is very small.

We may now consider what we ought to do to achieve the closest control. Reverting to the chain of time lags, we see that the first will be influenced by the detail design of the thermo-couple (with its sheath, if any) and by its position in the furnace. Clearly, the thermo-couple and sheath should be such that it will quickly experience a change in temperature, and it should be put in the furnace, if possible, where it will "see that change coming."

In this connection the test shown in Fig. 4 will be of interest. Two thermo-couples were installed in a small electric furnace. One of the thermo-couples had a large time lag by virtue of a heavy sheath, while the other had no sheath, and was arranged to give a very quick response to change of temperature. At the start of the test the slow thermo-couple was connected to an automatic control indicator panel, broadly like that in Fig. 3, and the furnace was controlled by the temperature as experienced by that slow thermo-couple. The quick thermo-couple was connected to a recorder acting as a tell-tale, and resulted in the

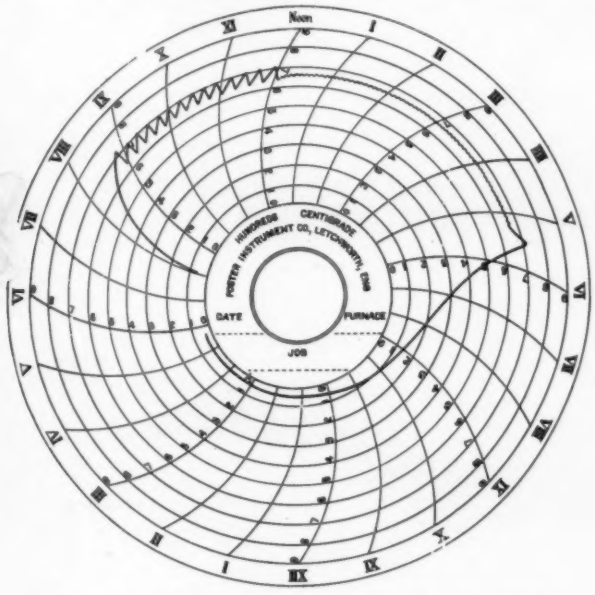


Fig. 4.—Record of automatic control by thermo-couples with large and small time lags.

record which shows large sharp oscillations of temperature. In this part of the record we see that the quick thermo-couple, which might be said to follow the furnace temperature exactly and instantaneously, experienced large oscillations due to the time lag of the slow thermo-couple.

Subsequently, without changing anything else, the quick thermo-couple was put on to the control and the slow thermo-couple on the tell-tale recorder. The amplitude of oscillations is now so small as to be barely distinguishable from a constant value. This latter part of the record is therefore typical of the temperature as experienced by material under treatment when the furnace itself is controlled by a quick thermo-couple. The little upward kick at the end of the record is due to the fact that the control was thrown out of action before the current was switched off from the furnace, and shows, incidentally, that the uniformity of temperature was solely due to the correcting action of the control; the furnace was quite ready to "run away."

This test shows clearly how important it is to arrange the thermo-couple so that it will quickly experience change in furnace temperature. The indicator pointer will at once move to follow such a temperature change, and, with the rapid periodical depressions mentioned above, the control valve will be operated to close in an extremely short

time after the change in temperature has penetrated to the thermo-couple. Clearly the valve or other control should be comparatively close to the burner or other apparatus for producing heat, unless, of course, it is electrical, when the response will be instantaneous after the closing of a switch, no matter what the distance.

We are now brought to the point where, obviously, the nature and design of the furnace itself comes in, and here it is not possible to lay down any general rules as to what should be done to secure prompt change in the furnace temperature: each case must be dealt with on its merits, but much can be done even with an existing furnace to secure the best results. Obviously, large variations in the available supply of heat will operate against close control, and here, for instance, a gas pressure governor may be valuable, or special arrangements with an oil furnace to secure uniform head and uniform fluidity in the oil supply. These two items are mentioned purely to illustrate the kind of precautions which should be taken.

In conclusion, it will be evident from the foregoing remarks that the best results can only be achieved by close collaboration between the makers of the instrumental equipment and the maker or the user of the furnace or other plant under control. It is quite clear that sweeping claims or guarantees as to closeness of control cannot be made by either party or partner in the ultimate result without reference to what can be done by the other partner.

One last matter is interesting from a technical point of view, and also psychologically. In the ordinary sense of the word, the automatic control pyrometer can have no power of prediction; it can only deal with the state of affairs at the moment. On the other hand, a human operator, controlling the furnace by hand, would be imagined to have that power of prediction, and, theoretically, he ought to be able to control the furnace temperature in the light of what he expects to happen within closer limits than the automatic control gear can achieve. But, owing to the fallibility of the human element, the most careful tests have shown that hand control, even most carefully carried out, cannot come "within streets" of what the automatic gear can achieve when properly installed.

Thermal Insulation with Aluminium Foil

The light weight of aluminium foil air-cell insulation, and its excellent insulation properties, make it especially suitable for use in the transportation industry.

THE principles governing heat flow by conduction, convection, and radiation have long been known, but their application in the production of aluminium foil air-cell insulation is a relatively recent development. By combining the low thermal conductivity of air with the low emissivity or radiating power of bright aluminium foil in a structure designed to minimise air convection currents commercial success has been obtained.

Quiet air is one of the best available mediums for preventing heat transfer, and the practical problem resolves itself into a determination of the best structure for confining the air in cells so as to eliminate heat transfer by convection and radiation. The most practical structure for any purpose may be a compromise between maximum thermal efficiency and cost. Some of the fundamental information necessary for the commercial design and utilisation of this type of insulation has been determined.

There are two general methods of using aluminium foil for insulation. One is to provide a framework which supports the aluminium foil and forms a series of air cells between the bright foil surfaces; in the other, the foil is first crumpled and then partially stretched, so that the resulting wrinkles in the foil separate the sheets when they are laid against each other, and provide the necessary separation and air cells.

The various factors determining the efficiency of aluminium foil air-cell insulation are analysed by Ralph B. Mason,[1] and the insulation value of a variety of structures determined experimentally give interesting results. In these experiments aluminium foil insulations of the plain air-cell type, and approximately 2 in. (5·08 cm.) thick, have been tested in a guarded hot-plate apparatus. The results indicate that the most efficient structures approach the conductance of still air. The distances between foils in these tests varied from $\frac{5}{8}$ in. to $\frac{1}{4}$ in. The insulation which gave the highest resistance to the flow of heat was the one which had the $\frac{1}{4}$-in. spacing. The insulation with a distance of $\frac{5}{8}$ in. between foils was the poorest insulation, and, judging from the temperature coefficient, considerable heat was transmitted by convection. For spacings less than $\frac{1}{2}$ in., the ratio between the measured conductance (corrected for radiation) and the conductance of still air was practically constant.

Aluminium foil insulations with corrugated separators between the sheets of aluminium foil were slightly inferior to the plain air-cell type. The baffle effect of the corrugated separator upon the convection streams, causing cold air to be conducted by many paths directly from the cold to the hot surfaces, the conductance of the separator itself, and the covering of a portion of the aluminium surface, have been suggested as factors which cause a poorer insulation against the flow of heat.

Insulation structures containing crumpled foil were somewhat inferior to the corrugated structures. The amount of heat transmitted by convection appeared to be greater. Here again there are a large number of baffles to deflect the convection streams of air, and convection streams apparently flow directly from the hottest foil to the coldest foil around the edges, unless special precautions are taken to prevent this. Also heat may be conducted from one foil to the next directly through the points of contact.

A typical cold-box apparatus was used as a check upon the results obtained by the guarded hot-plate apparatus. The results which were obtained showed good agreement between the two methods of testing. It was also possible to obtain a low mean temperature in the cold-box apparatus with solid carbon dioxide as the refrigerant. The determination of the rate of evolution of carbon dioxide gas by means of a gas meter is a novel method for the measurement of the rate of heat input to the cold box.

Aluminium foil makes an excellent radiation shield, and with aluminium foil it is easy to eliminate practically all of the heat ordinarily transmitted by radiation in an insulation of the air-cell type. The results obtained show that by careful design it is possible to construct an insulation from foil in which there is little or no convection. By using the minimum amount of separator material of high thermal resistance, the foil insulation can be made to approximate the thermal resistance of quiet air. The secret of this outstanding performance of aluminium foil insulation lies in the low thermal emissivity of the bright aluminium surface.

[1] *Industrial and Engineering Chemist*, Vol. 25, No. 3, pp. 245-255.

Alloy Steel Castings

By W. F. Rowden.

The need for steel castings of high strength combined with toughness and resistance to impact, abrasion, high temperatures and pressures has given an impetus to the production of alloy steel castings. In this article the author emphasises many factors that are of vital importance in their production.

THE ordinary carbon steels available for castings serve to meet the demands for a very large number of engineering purposes. There are, however, a number of applications where the limitations of carbon steels preclude their use, and the founder is called upon to supply castings of high strength combined with toughness and resistance to impact, abrasion, high temperatures, and high working pressures.

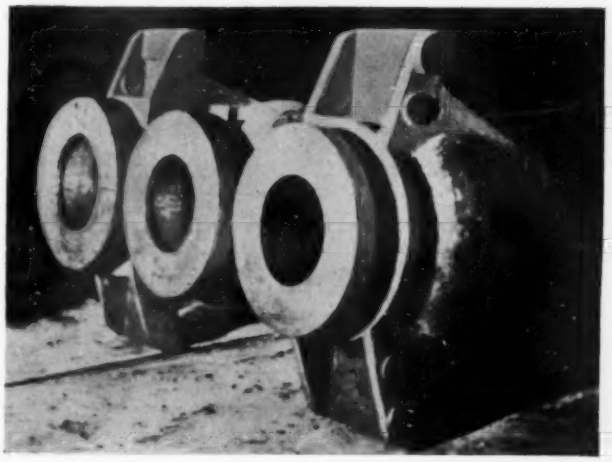
In order to obtain these properties, it is necessary to turn to the use of alloying elements, but it must be borne in mind that these different properties call for different alloy metals, and that something in the nature of a compromise is often necessary to meet specifications. The introduction of even fractional percentages of the various alloying elements in common use adds considerably to the cost of the castings, and, in addition, in order to obtain the full benefit of these elements, it is generally necessary to subject the castings to some form of heat-treatment. The manufacture of alloy ingot steel demands the highest skill of the steelmaker, and this applies with equal emphasis to alloy steel casting charges.

Probably the greater percentage of steel for castings is made in the acid open-hearth and electric furnaces, and a brief description of the methods necessary to ensure sound steel made in the acid open-hearth furnace, commencing with the raw materials used, will be of value. The charge should consist of clean scrap having low phosphorus and sulphur content, the percentage of turnings if used should be kept down to reasonable proportions—say, not exceeding 10% of the charge, and these should be clean, to avoid any tendency to oxidisation in the bath. With regard to the amount of pig iron used, no definite figure can be stated, as this depends on a number of circumstances, such as the type and method of operation of the furnace, and on the final carbon desired in the castings. For example, in the manufacture of a charge to contain up to 0·20/0·40% C. sufficient pig should be used to ensure the bath containing from 1·00 to 1·50 carbon when clear melted.

When melting down, the amount of air used should be kept down to avoid over-oxidation. When clear melted, it may be necessary to use a small quantity of ore to get the charge on the boil; this, however, should be used sparingly, especially if the charge is on the cold side. It has been found that a good basis for the amount of ore to use is ½ to 1 cwt. to 10 tons of steel fed every 10 mins. This amount of ore used over the time stated will bring a charge on a boil just as quickly as using large quantities. From the time the charge commences to boil until finally tapped is the most critical time, and the quality of the steel depends on the amount of care exercised during this period.

In order to determine what carbon the bath contains, it is as well to take out a sample for estimation before starting to boil the charge down. Before commencing the feeding of ore a sample should be taken, and the appearance of the slag and sample should enable the steelmaker to judge whether ore should be used. If the slag shows any tendency to lift in the spoon, ore should be kept out at all costs. This condition is due to either lack of heat or else to an overfeed of ore at some previous time. If the sample and slag show no signs of lifting, then ore can be given. The author has found that on a 20-tons charge, 1 cwt. of ore at a time is sufficient, and on a 50-tons charge 2 cwt. After 15 mins. has elapsed a further sample is taken and again fed if conditions justify. It is found that if these instructions are adhered to, regular quantities of ore can be given at periodic intervals, and that the slag and samples can be maintained in perfect condition. When it is judged that the carbon is about 0·50% it is as well to have a sample taken for analysis. However good the observer may be in estimating carbon by the boil and the fractured sample, mistakes can be made, especially in the case of alloy steels, fractures of which are often very misleading. The whole object in keeping down to a minimum the amount of ore used is to allow the charge to attain a state of equilibrium between slag and steel, which also means that the minimum amount of gases remain, and this state is approached the lower the carbon content of the bath. It is for this reason that many steelmakers prefer to boil down to, say, 0·15/0·20% carbon, when making a steel to contain from 0·25% to 0·45% carbon and to recarburise by the use of speigel, etc. Above the higher limit the bath is brought down to a figure which will allow for the minimum addition of carburising material without undue cooling of the charge. Coming back to the stage when the carbon is in the region of about 0·50% before adding any further quantities of ore, sampling should be continued every ten to fifteen minutes; generally it will be found that a progressive decrease in carbon content is shown, and the bath may be left to come down to the desired carbon content without the necessity of ore additions. It may be necessary to add small quantities of limestone to avoid the slag thickening up unduly.

In order to stop a further reduction of carbon—*i.e.*, to stop the boil, silicon is added to combine with the oxygen present, which is reducing the carbon. If the charge has been properly worked it will be found that about 0·10% of silicon and about the same percentage of manganese are present in the steel. The amount of silicon actually



By courtesy of Atlas Foundry & Eng. Co. Ltd., and C. A. Parsons & Co. Ltd.

Fig. 1.—Steam chest in molybdenum steel, weighing 8 tons.

By courtesy of Metropolitan Vickers Electrical Co. Ltd.

Fig. 2.—Sectioned casting in molybdenum steel for high temperature and pressure purposes.

required is very small, and 0·10% for ingot steel will be sufficient to ensure perfect soundness of ingot.

Castings are generally specified to contain 0·30% of silicon as a minimum, the extra amount necessary to produce this quantity will make soundness positive. The adjustment of carbon and manganese can be made by the use of spiegel and ferro-manganese, which should be added in the furnace, and it is unnecessary to use any special deoxidisers; materials should not on any account be added in the ladle. Before tapping, a sample is poured, and if the melting has been carried out carefully and as described, it will be found perfectly sound. From the time the silicon is added to tapping is generally about 25/30 mins. In tapping, care should be taken to avoid sand and dirt being picked up from the tap-hole and launder, the ladle should also be clean, otherwise inclusions of foreign matter will be found in the steel.

Following the procedure outlined above, the weight of ore required is comparatively small. Unless the amount of ore used is strictly controlled a condition can easily be reached in which the bath becomes overcharged with oxides, and when the time comes for finally deoxidising, although the amount of silicon added will give what appears to be a sound sample immediately prior to tapping, a reaction will still be proceeding and the evolution of the gases taking place during casting will result in "blown" steel. That this reaction does take place can be shown by an analysis of iron, manganese, and silicon oxides, in a slag sample taken before and after tapping, when it will be found that the iron oxide content is reduced, the silicon and manganese in the steel having absorbed the excess oxygen, and the oxides of the metals so formed having gone into the slag.

No mention has been made of the addition of alloying elements to the steel bath. This does not introduce any difficulties providing the additions are made at the right time. Alloys such as nickel and molybdenum, which are not subjected to appreciable loss by oxidation, should be added during the early stages of the "boil," but chromium, silicon, manganese, and vanadium which are liable to loss by oxidation are added just before tapping; sufficient time, however, should be allowed to ensure their thorough solution in the steel. In the case of some alloy steels, notably those containing chromium, the charge will have to be worked at a higher temperature than normally to allow for "sluggishness" in running, which is evident in these types of steel.

With regard to actual compositions of alloy steels suitable for castings, these are many and varied, and space does not permit of a detailed account of the specifications. As was pointed out earlier, heat-treatment in some form is almost essential in the production of alloy steel castings. The plant at the disposal of the manufacturer for carrying out heat-treatment governs to a large extent the analysis of the casting since some manufacturers of steel castings are not in a position to carry out oil-hardening. Whatever heat-treatment is carried out, it should be borne in mind that alloy steels are more sensitive under such treatment than carbon steels, and for this reason it is essential that great care should be exercised in treatment, particularly when a casting is of complicated design. Here, collaboration between customer and founder can do much to lessen the manufacturer's difficulties by obviating as far as is possible abrupt changes of section, which not only introduce difficulties in casting, but frequently are the cause of cracks developing in heat-treatment.

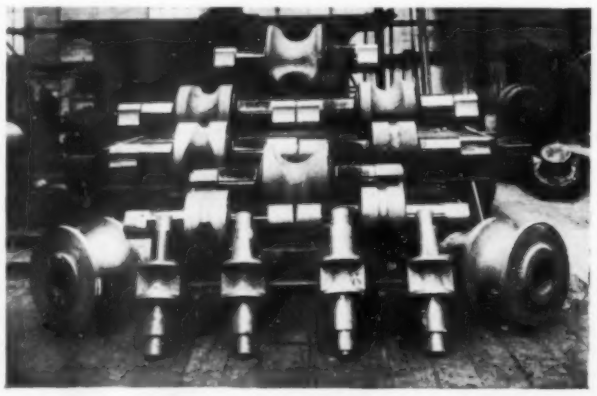
Another frequent source of trouble in alloy castings is due to allowing the castings to remain exposed to varying climatic conditions after stripping. Alloy castings, immediately after stripping, should be placed in the annealing furnace and subjected to a thorough anneal at a temperature sufficiently high to completely break up the casting structure. The rate of heating in the annealing furnace is of great importance, and castings should never be charged into a hot furnace, they should be brought up very slowly from a low temperature to that required for annealing, and cooling should be equally slow and free from sudden chilling by cold air. Neglect of these precautions may lead to serious deep-seated internal stresses being set up which cause internal ruptures not visible on machining, but liable to result in premature failure in service. No matter how good a steel casting may be when it is made, it may be completely ruined by careless heat-treatment, and the greatest care is necessary in cooling down slowly and evenly after annealing, normalising, air-hardening, and tempering.

The effects of various alloying elements in castings are more or less identical with those found by their use in constructional alloy steels. Heat-treatment and analyses also follow the same lines.

Although manganese and silicon are not generally regarded as alloys, there are quite a number of steel castings made in which these elements play the part of alloys. In the case of manganese, if the percentage is increased to about 1·5 or 1·6%, the additional manganese has the effect of giving improvement in tensile and yield-point without

Fig. 3.—Group of Pilger rolls in steel containing a combination of alloys.

By courtesy of R. B. Tennent, Ltd.



undue sacrifice of ductility ; these properties being obtainable in the normalised and tempered condition. If it is deemed safe to water-harden, then quite a range of properties is obtainable, if this is followed by tempering. Silicon also gives increased mechanical properties. West, in a recent paper before the Sheffield Branch of the Institute of British Foundrymen, gives some interesting figures on the effect of progressive increases of silicon.

Chromium is used primarily to obtain increased hardness, and at the same time the strength is raised. In order to obtain the best effect, a treatment other than annealing is desirable, when the penetrating effect of chromium is very noticeable. The status of copper as an alloying element does not appear to have been definitely established ; it is said to provide a cheap means of increasing the strength when used in conjunction with other elements, for example, chromium ; it is also said to increase the resistance to corrosion when present in small quantities.

Nickel has the effect of increasing tensile strength, ductility, and resistance to shock, and these properties are obtained both in the normalised condition and when the steel is hardened and tempered. Nickel also exerts an influence in retarding grain growth.

Molybdenum acts in a somewhat similar manner, and a high elastic limit tensile ratio is obtained by its use. The term "elastic limit" is used here in its true sense as distinct from the yield-point. In the heat-treated condition, molybdenum also has the effect of promoting uniform depth hardness. Its property of being able to counteract the effect of temper brittleness accounts for its use in highly stressed complicated castings. To obtain high impact values it is only necessary to cool slowly from the tempering temperature. By choosing a suitable composition which will air harden, the dangers of distortion through quenching in a liquid medium are overcome.

Apart from these properties, molybdenum is used in carbon steel castings which are required to work at temperatures considerably above atmospheric temperature, the effect of molybdenum being to increase the creep strength. Fig. 1 shows a steam chest casting weighing about 8 tons. In comparing two carbon steels of same carbon content, one without, one with molybdenum, a yield-point of 10 tons per sq. in. is obtained at 450° C. without molybdenum, but this is raised to 16 tons per sq. in. by the addition of a small percentage of molybdenum, both being tested under identical conditions, these figures were obtained from casting illustrated. Fig. 2 shows a sectioned casting, also of molybdenum steel, from which it will be seen that this type of alloy steel possesses good casting qualities. This casting was prepared as an experimental casting, and was cut to examine the sectional structure before the steel was adopted on a production basis. It is of interest to note that the metal was prepared in a high-frequency furnace for casting.

Vanadium is used to refine the grain structure and also to obtain higher elastic limit. Whilst the alloying elements mentioned above are used to quite a considerable extent alone, a wide range of physical properties are obtained when these alloys are used in conjunction with one another. These physical properties can be obtained by a careful study of the alloying elements and their characteristics, and a number of compositions are available which, whilst all giving the same desired qualities, vary considerably in cost. It is therefore of direct economic concern to the maker of steel castings to find out what composition will give him the desired results at the minimum cost, not only in alloying elements, but also in direct charges in subsequent heat-treatment. To give a few instances of combinations which yield alloy steels covering a wide range of specifications, there are the manganese-chromium, manganese-nickel, manganese-molybdenum, and manganese-vanadium as binary alloys. The ternary alloys include manganese-chromium-nickel, manganese-nickel-molybdenum, chromium-nickel-molybdenum, and chromium-molybdenum-vanadium. Quarternary, manganese-nickel-chromium-molybdenum, nickel-chromium-molybdenum-vanadium, and manganese-chromium-vanadium-molybdenum.

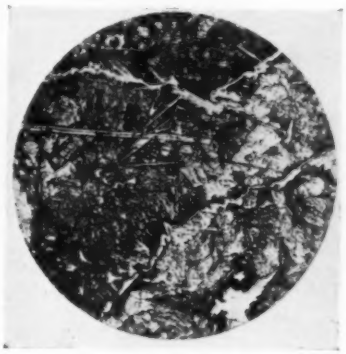


Fig. 4.—Structure as cast × 300.

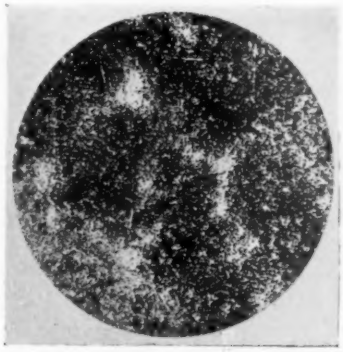


Fig. 5.—After heat-treatment × 55.

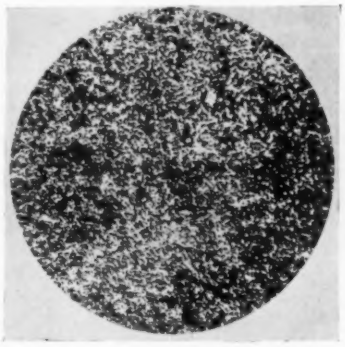


Fig. 6.—After heat-treatment × 300.

The structure of a quarternary alloy steel, reduced about half size.

As an example of what may be achieved with a combination of alloys, Fig. 3 illustrates a group of Pilger rolls. To withstand the heavy duty in service, these rolls are required to possess strength with toughness, good wearing properties, and in addition they are called upon to withstand stresses through varying temperature fluctuations. This combination of properties is obtained by the carefully adjusted use of molybdenum, nickel, chromium, manganese, and carbon. Through a knowledge of the functions of the various alloys used, a simplified form of heat-treatment can be evolved. Fig. 4 shows the structure as cast, and Figs. 5 and 6 after subsequent heat-treatment.

In conclusion, the manufacture of alloy steel castings involves attention to a large number of points which may be summarised as follows :—

1. Selection of raw materials.
2. Good melting practice.
3. Co-operation between founder and customer.
4. Care in treatment of castings after castings.
5. Heat-treatment.
6. A knowledge of the functions of the various alloying elements available.

The author wishes to express his gratitude to Mr. J. L. F. Vogel, of High Speed Steel Alloys, Ltd., for his help and kind permission to publish much of the information contained in this article.

Die Casting

By A. H. Mundey
(Fry's Metal Foundries, Ltd.)

MUCH has been written and described in recent years on die casting, and it would appear to be altogether unnecessary to define the term, yet some confusion of mind is occasionally met as to the nature of the products and the fundamental principles of the methods of manufacture.

As the name indicates, it is essentially a casting process. Metal in a fluid or almost completely fluid condition, is poured, or forced under pressure, into a highly finished mould, the product being a casting which leaves little or nothing to be done to it in the machine shop. It is accurate as to dimensions to a remarkable degree. Designs of such a highly intricate nature are mere commonplace, yet it is fair to say that no production engineer would care to undertake their manufacture by any other method.

The process must be distinguished from die stamping and die pressings. These are altogether admirable methods of manufacture, in some cases of necessity competing successfully from an economic standpoint with die casting, but are different; their sphere of application is more limited, and their products lack many features which are absolutely essential if the full advantages to be obtained by modern die casting are desired.

The range of the process is now so great that it is fair to say that in whatever circumstances a large number of similar articles in non-ferrous metals is required, the engineer designer is well advised to consider die casting as a method of production. Naturally, in many cases, it is not the most appropriate method, but the surprising variety of its applications entitles it to earnest consideration in the early stages of design.

The alloys used present almost as wide a choice as the types of design and purpose; they range from lead and tin alloys to high-tensile brasses, and even in special cases to cast iron. The writer has on occasions claimed that the largest makers and users of die castings are the printers. This is still a true statement, for in every great newspaper office hundreds of thousands of completed castings in the form of type or type slugs, perfectly finished without trimming, are used every day or night for our daily newspapers.

It is not this type of die casting that is generally visualised when die castings are mentioned in these days, but the thousand and one machine details, the fittings for automobiles, telephone parts, wireless and gramophone fittings, electrical machine parts and fitments; these articles, which are literally too numerous to enumerate, are rightly regarded as legitimate die castings.

History of the Process.

About a quarter of a century ago some ingenious Continental engineers introduced the industry into the service of the general engineer and manufacturer. Excellent dies were designed and made, and machines were constructed for the production of the castings under pressure. Unfortunately, these inventors had but an elementary knowledge of metallurgy, and practically none concerning the physcial constitution of alloys. Mixtures of metals were made which produced good-looking and sharply defined castings, but, alas, the alloys were very unstable. Age-hardening troubles arose after important articles had been in service a few months, cracking, distortion, and swelling developed, and the whole art of the die caster was discredited.

Fortunately, the cordial and active co-operation of the engineer-designer and the metallurgist was obtained; alloys were made which are suitable for the novel methods of casting, and capable of remaining stable and true in the trying conditions imposed, and now the public can be served with confidence in the very wide range of metals and alloys at the service of the foundry.

At first the efforts of the die caster were directed to the production of castings in permanent or long-life moulds, generally of iron or steel, thus eliminating the great loss of time and effort spent on the floor or bench of an ordinary foundry in producing moulds in sand and loam, using wooden or other patterns.

A second object aimed at, and successfully attained, was the production of a close structure to the metal on account of the chilling effect of the iron moulds, preventing the grain growth or coarsely crystalline structure seen in many ordinary foundry castings. These objects being achieved in such large measure, the natural development was towards the perfection of the dies or permanent moulds; a constantly increasing standard of accuracy and finish was imparted to the moulds; cores, plain or screwed, were included. Intricate parts were introduced which enabled the die to be built up and locked before the casting operation and to be stripped afterwards mechanically.

Inserts of other metals were introduced so that they could be imprisoned safely in their proper places in the finished casting. Clever devices were provided to eject the casting safely just at the moment when its strength and rigidity were at the minimum. Thus the finished die casting is now delivered from the trimming shop ready for assembling, with all holes screwed when required, no drilling, turning, milling, or other machine operations being necessary; or, if desired, with all bosses carefully spaced ready for the jig for drilling when superlative accuracy is demanded. Obviously plating, polishing, and colour finishing are often required, but a close study of the character of the alloys has robbed these operations of all their terrors.

Gravity and Pressure Casting.

The industry has now reached such a stage that attempts to classify the processes employed are almost vain, for they are found to interchange and overlap to a remarkable degree. Two main divisions are to be emphasised, gravity casting and pressure casting. The names are self explanatory. In the first-named the molten metal is poured into the mould from a ladle or melting pot, relying upon gravity to ensure a well-filled mould, the contained air being ejected through cunningly placed vents. Bottom pouring is often employed with success. It is held by many authorities that the soundest and best castings are those which are gravity poured, as the metal tends to solidify from the bottom and to displace the air in the most natural way. In a general way any type of alloy which can be employed can be cast as a gravity die casting, but there is a very important qualification to be made. It is by no means true that any casting can be produced equally well, or even at all, by gravity casting as by the pressure process.

In the early days the principal die castings were made in low-melting-point alloys, the gravity method being employed. Printers' type, bullets, toy soldiers, and statuettes were among the well-known products. In order to cheapen and reduce the weight of relatively unimportant castings, like toy soldiers and some statuettes, the metal was poured into the mould, alloyed to remain until a solidified lining to the mould was produced, then the whole was quickly inverted, allowing the still fluid metal of the

interior to run out, thus producing a perfectly satisfactory hollow casting. This is termed slush casting. It is frequently regarded as a rather poor class of production, but those critics who treat it with a certain contemptuous indulgence would probably be surprised at the number and quality of artistic details produced in metal by the slush process. High-class finishing and enamelling complete a very attractive piece of work.

Type casting of all grades, toy metal casting, and slush metal statuettes are all made of the ternary metals of lead, tin, and antimony, the higher grades of products generally demanding the larger proportion of tin. The making and lining of bearings with white anti-friction alloys is often a die-casting operation. Standard bearings for the best-known auto-cars can now be purchased from stock, thus saving much delay and expense. On the other hand, certain railway carriage bearings are actually white metalled by pressure die casting ; the shell is most carefully cleaned, tinned, heated, and the selected anti-friction metal injected under pressure around a mandrel.

The whole range of white anti-friction alloys are capable of use in die-casting operations, each in its appropriate place. Another typical case of very large production in die casting by the gravity process is the preparation of battery plates ; these are surprisingly beautiful castings. The alloy used is a binary one of lead and antimony. Few engineers who are unacquainted with this industry would credit the high standard of work involved in the fine-meshed gratings of many of the best-known battery plates.

It is in the application of the series of zinc-base alloys that the great advance of die casting is most evident. In fact, it was not until alloys of this character were employed for articles in common use, and were cast in so-called permanent moulds, that the process received its now well-known and accepted name.

These alloys made wonderful castings, but, as indicated earlier, the whole industry was endangered by the want of metallurgical knowledge on the part of the pioneers. Mr. Marc Stern, in his excellent work, pointed out that the early zinc alloys were very sensitive at high temperatures—hidden cracks occurred ; they were infected with destructive intercrystalline oxidation and so-called "ageing," which greatly reduced the strength and altered the shape and size and structure of the product. In order to overcome mechanical difficulties, doses of lead or tin, and even antimony and bismuth, were sometimes added by the operator, resulting in broken and swollen castings.

It is gratifying to know that these faults have been remedied and the consequent difficulties overcome, but the fact cannot be overstressed that only the best is good enough in respect to the metals employed.

Reliability of Alloys Used.

There is ample evidence of the reliability of the alloys now used by reputable die-casting firms, as demonstrated by experiments under research conditions and the behaviour of castings of intricate design in everyday service for years, frequently in severe conditions due to varying temperature and humidity.

The zinc-base alloys are divided into two main classes.

1. Those in which the hardening constituents are copper and tin, in varying proportions as circumstances demand, together with a small amount of aluminium.

2. Those in which copper and aluminium are the hardening and toughening constituents; in these a small proportion of magnesium is generally added.

The alloys in class 1 usually contain copper, 3 to 4%, and tin, 5 to 9%—the tin is sometimes increased considerably,—aluminium, 0·2 to 0·5%. These alloys are fairly easy to manipulate, they make excellent castings, have a tensile strength of upwards of 10 tons. They give little or no elongation, they have a density of about 7·0, and their porosity is low, 3 to 4% Their finish is very good, and their dimensional accuracy is remarkable.

The alloys of class 2, those hardened and toughened by copper and aluminium, are the mainstay of the industry in zinc-base alloys. Many workers in our own country, in Canada and the United States, and on the Continent, have given great attention to this section.

The first requirement is high purity. Electrolytic zinc, electrolytic copper, and the highest grade of aluminium are alone admissible.

TABLE I.

COMPOSITION OF ALLOYS UNDER INVESTIGATION. ZINC BASE.

Alloy Mark.	Cu.	Sn.	Al.	Ni.	Pb.	Mg.	Cd.	Density.
6 R M	3·17	5·67	0·41	—	—	—	—	7·148
7 R M	3·16	7·40	0·36	—	—	—	—	7·143
8 R M	3·72	9·75	0·98	—	—	—	—	7·085
9 R M	3·07	13·82	0·44	—	—	—	—	7·070
10 R M	3·11	22·31	0·29	—	—	—	—	7·202
11	1·2	9·7	0·98	—	—	—	—	—
12	1·06	8·35	0·37	1·09	—	—	—	7·131
13	3·66	9·65	0·86	—	—	—	0·97	7·128
14	2·72	—	3·95	—	—	—	—	6·77
14 B	3·07	0·28	4·64	—	—	—	—	6·73
15	5·14	—	4·16	—	—	—	—	6·85
16	7·02	—	4·02	—	—	—	—	6·905
17	3·03	—	3·87	—	0·80	—	—	6·78
17 A C	3·04	—	3·44	—	0·75	—	—	—
2 A E	3·02	—	4·07	—	—	0·095	—	—
2 A H	2·94	—	4·02	—	—	0·107	—	—

TABLE II.

TO SHOW THE EFFECT OF TYPE OF PULL ON LEVER ACTUATING PLUNGER.

Alloy No.	Quick Pull.		Slow Pull.			
	Porosity, %.	Tensile Strength, Tons per Sq. In.	Porosity, %.	Tensile Strength, Tons per Sq. In.		
6 R M	—	—	3·69	9·81		
7 R M	6·04	9·75	3·40	10·34		
8 R M	7·3	9·57	3·09	10·66		
9 R M	7·40	8·84	2·37	10·12		
10 R M	—	—	4·09	9·00		
11	—	—	—	9·11		
12	—	—	3·16	7·62		
14	6·90	18·00	3·63	17·61	Standard gate.	Average of 20 tests.
14	5·40	18·84	3·70	18·14	Enlarged gate.	" "
15	7·37	19·16	2·33	20·73	Standard gate.	
15	4·87	21·22	4·23	20·96	Enlarged gate.	
16	6·70	21·11	4·17	22·10	Standard gate.	
16	4·80	22·13	3·27	23·24	Enlarged gate.	
17	4·25	17·51	4·10	17·24	Enlarged gate.	Average of 20 tests.
Z A E	—	22·02	—	—	Enlarged gate.	" 11 "
Z A H	—	22·27	—	—	Enlarged gate.	" 5 "

The composition of the zinc-case alloy generally used in this country is copper, 3% ; aluminium, 4% ; magnesium, about 0·1% ; zinc, electrolytic, 99·99 purity, remainder. In the United States the magnesium content is rather lower, otherwise the alloy designated No. XXI. by the American Society for Teating Materials is similar to that just mentioned. Another alloy used by American workers is known as No. XIX., is copper, 2% ; aluminium, 4% ; magnesium, 0·01% ; nickel, 0·02%.

The ductility of these alloys is quite marked, but it should be emphasised that it is not strongly evidenced in the tensile tests by good elongation, and a doubt is sometimes raised by engineers in this connection. The ductility is demonstrated by the behaviour under torsion tests, a very considerable amount of twist and permanent deformation is obtained before rupture occurs. This was reported by Lancaster and Barry.[1] Cartland and Lancaster have prepared many specimens on the large-works scale, demonstrating the features of the alloys, including those with additions of rare metals, which are specially promising.

In Tables I. and II. a number of test figures are given. These were obtained by Russell and his fellow-workers, at Sheffield University, in an investigation under the British Non-ferrous Research Association. These figures have been confirmed by many private workers, and also by the researches made and reported by the American Society for Testing Materials.

[1] Journal Institute of Metals. Vol. xliii.

Aluminium Alloys.

Some of the most valuable work, both on research and on large-works scale, has been carried out with aluminium alloys. It is safe to say that die casters have now at their disposal a series of thoroughly reliable light alloys, capable of the best class of production by either gravity or pressure-casting methods.

TABLE III.

ALUMINIUM ALLOYS. MECHANICAL PROPERTIES OF DIE-CAST TEST-PIECES. TESTED DIRECT WITHOUT MACHINING.

—	Condition.	M.S. Tons per Sq. In.	E. % on 2 in.
	Large Test-piece.		
"Y"-alloy	As cast	14–14·5	1·5–2
	Heat-treated	17–17·5	2
Si 12%	Modified	13–13·5	10
Cu 4%, Si 3%	As cast	9·5–10	1·5–2
	Heat-treated	14·5	2
	Small Test-piece.*		
"Y" alloy	As cast	14–14·5	1·5
	Heat-treated	18–19	2
Si 12%	Modified	13·5–14	10
Cu 8%	As cast	9–10·5	3–4
Cu 4%, Si 3%	As cast	9·5–10	4–5
	Heat-treated	14·5	3

* Elongation measured on 1 in. gauge length.

The investigations made under the auspices of the British Non-ferrous Research Association, and carried out by Archbutt and his colleagues, guided by Rosenhain, at the National Physical Laboratory, give confidence to all concerned. The castings were of test-pieces and also difficult and typical die castings, from which test-pieces were taken, and which enabled the experimentalists to give reliable figures, a few of which are shown in Table III.

The 12% silicon and the copper-silicon alloys yielded sound castings with good density values and an absence of cavities. The hollow castings produced in these experiments were subjected to a hydraulic pressure test of 1,000 lb. per per square inch for 30 minutes and showed no signs of leakage.

Copper-rich Alloys.

The alloys of the copper-rich series are of the greatest interest to the engineer.

The research by Genders and his colleagues at the Research Department, Woolwich, under the guidance of Dr. Harold Moore, also under the auspices of the British Non-ferrous Research Association, yielded figures which may be looked upon as completely reliable. The report on the complete series of these results is to be found in the *Institute of Metals Journal*, vol. xl., No. 2, 1928.

It must be clearly understood that die casting is a branch of industry which has become highly specialised. It cannot be undertaken by unskilled labour in an odd corner of a works. To obtain the best results the co-operation of skilled die designers and die makers, casters and experienced metallurgists must be secured.

TABLE VI.

COPPER RICH ALLOYS. TESTS OF DIE-CAST TEST-PIECES.

Material.	Maximum Proof Stress, Tons per Sq. In.		Maximum Load, Tons per Sq. In.		Elongation, %	
	Round Piece.	Flat Piece.	Round Piece.	Flat Piece.	Round Piece.	Flat Piece.
Aluminium-bronze (Cu 89·6, Al 10·4)	10·2	14·3	23·6	28·4	23	5
Iron-aluminium-bronze (Cu 87·8, Al 10·2, Fe 2·0)	12·1	13·0	33·4	35·0	14	10
High-tensile brass (Cu 59·2, Al 3·5, Zn 33·1, Mn 4·2)	27·9	20·7	41·8	38·0	7	4
Aluminium-brass (Cu 59·9, Al 3·5, Zn remainder)	21·4	18·6	42·0	33·2	7	4
Aluminium-brass (Cu 69·2, Al 4·3, Zn remainder)	15·1	21·7	37·6	36·1	17	7
Pure 60 : 40 brass (Cu 59·6, Zn remainder)	7·6	9·0	24·0	25·3	29	28

Die-casting Machines.

A description of the methods and machines at present in use for the production of die castings would require a whole volume. The moulds or dies have gradually developed from simple two-part to multiple-part devices, having many and complicated cores and formers which are required to be dismantled often, by the use of ingenious mechanism between the casting operation proper and the stripping and ejection of the casting. This is true for both gravity and pressure casting methods. The former process, which is simple in principle, has grown to be quite an elaborate operation, and the castings produced are often very complicated in form and of considerable size. Thus some aluminium alloy gearboxes, produced by the engineering staff of Messrs. Leyland, weigh when finished about 56 lb., and are of surprising excellence.

Practically all the alloys which are employed in the industry are capable of gravity die casting but whilst this method is almost exclusively employed in aluminium bronze work it has been found that under very high pressure the modern zinc-base alloys, aluminium alloys, and even high-tensile brasses are cast with a degree of soundness and density, and with such a fine skin finish as cannot be attained by the gravity process.

The low-melting-point alloys, lead base, tin base, and zinc base of Class A are cast with great success with a simple plunger pressure machine, either hand operated by means of a long lever, or mechanically operated. The hand-operated method has advantages in that although laborious, the skill of the operator is exercised in giving the kind of impulse required for the particular casting to be produced; in some cases a sharp stroke is required, in others a long follow through is productive of better results.

For alloys of the higher-melting-point series, that is aluminium alloys, and the yellow metals, simple plunger machines are not suitable, as too great a duty is imposed upon the pump barrel, consequently air pressure is employed.

Many devices are used to obtain the necessary air pressure without causing too great disturbance of the molten metal; the early methods were an adaptation of the chemist's wash bottle or scent-spray principle, then a U-shaped tube was adopted, and from this the well-known goose-neck machine was evolved. This method finds great favour, the vessel oscillates for each cast, the nozzle dipping into a metal container receives its supply of metal, then returns to operating position with the nozzle in communication with the aperture or sprue of the die. The air under pressure is then admitted and the metal is injected into the die. Other designs admit the air to an annular chamber above the surface of the metal in a vessel formed on the principle of a teapot, the flow being from the lower portion of the pot, thus ensuring a stream of metal free from æration.

A remarkable method used on the Continent, and in some cases in this country, provides for the amount of metal required for each cast to be contained in a small collapsible asbestos cup. Air pressure is applied and the metal is projected into the die. A large measure of success has attended this practice.

Finally, the Polak process, a very daring invention of Josef Polak, of Prague. The metal is held in a cup and a plunger is forced down upon its surface by hydraulic pressure, plus air pressure. The alloys, which are operated in a viscous, fluid condition are aided by their high surface tension, and the higher-melting-point alloys such as high-tensile brasses are operated whilst in a slightly pasty condition, just between the temperatures of solidus and liquidus. Castings which hitherto have been rightly regarded as impossible are produced with the greatest accuracy and with high finish.

One other feature which is obtainable by the use of high pressures is the remarkable soundness of the casting. Some interesting problems are involved in this; it is open to discussion as to whether the contained air, if any, is compressed to an infinitely small volume, or if the air remains in solution due to high pressure as in the case of carbon dioxide in the soda-water syphon.

Some Specifications Relating to Iron Castings

By Walter West

Efforts made to classify requirements of iron castings give the engineer and designer fundamental information upon which to work and the founder a basis upon which he can anticipate the behaviour of the metal. In this article the author deals with those characteristics which are closely related to tensile and transverse properties.

At the present time there can be no complaints in this country that specifications connected with the production of iron castings are exacting or excessively detailed. This is undoubtedly due to the appreciation which the originators of such specifications have that foundry work is governed by art and craft, both in respect of metallurgy, processes, and methods of production. Specifications in detail cover many requirements which are not of common desire, such as fatigue, strength, rigidity, impact, corrosion resistance, etc.

It is not within the scope of this article to consider special requirements such as corrosion and wear resistance, which entail a specialised view, but to the comprehension of those characteristics which are closely related to the general tests of tensile and transverse properties.

The recent attempt at classification of requirements of the British Standards Institute has a twofold advantage. In the first place, such classification, which can yet be further exemplified, gives to the engineer and designer fundamental information upon which to work, according to the peculiarities of design in respect of variations of thickness; and, in the second, the founder is placed upon a more equitable basis upon which he can anticipate the behaviour of the metal during solidification, and more truly correlate the mechanical properties of the metal in the casting to that comprised in the test pieces.

Even with such a standard of classification, it may be stated with a certain element of truth that the casting of test bars more truly represents the metal in the ladle than that in the casting itself, but when it is considered that short of mutilation of the resulting shape, the test bar of comparative thickness does give satisfaction, insomuch that some idea approximating reality is obtained of the physical properties of the metal, and is much more reliable than such calculations as can be made from the chemical composition alone. This factor alone justifies the consideration of results from standard sizes of test bars, as recommended by the British Standards Institute.

In many cases specifications call for independent tests to be carried out on the casting itself, and in the case of hydraulic pressure testing, perfection of mechanical properties is no guarantee against the rejection of the casting through imperfect sections. In other cases, wherein dimensional accuracy is demanded, no great difficulty should confront the manufacturer, as in one sense the natural behaviour of cast iron during solidification materially assists; it is, therefore, an attention to the details of moulding which is required, factors which are well within the art of the moulder's craft.

Specifications Affecting Mechanical Properties.

Grey cast iron is not just one material, but a genus which can be classified, whose physical properties are a direct function of the mass effect of chemical composition and after-treatment. The iron-carbon-silicon series of alloys which comprise grey iron as a whole contain the carbide-eutectoid "pearlite," pure iron, "ferrite," and excess carbon as free "graphite." Within the permutations of composition, from these elements alone and the structural make-up of these compounds, alloys of widely divergent properties can be obtained. There are three important factors, therefore, at least, which affect the final result and the meeting of specifications required.

1. The chemical composition of the metal.
2. The structural form in which the chemical combinations occur.
3. The conditions of the melting process, with its effect upon the after-treatment.

Modern research teaches that the structure of cast iron has a most important and direct bearing upon the mechanical properties, and that the structure is produced from a combination of the chemical constituents, and the conditions of melting and cooling.

It is generally recognised that a thick section of cast iron is relatively weaker than a thin section of the same composition, by virtue of the fact that the slower rate of cooling allows the growth of an increased size of graphite with a possible increase in the general grain size. Thus can the graphitic carbon element predominate and influence the mechanical properties of the resultant cast iron, if steps are not taken to effect a control both upon the amount present and the size in which it occurs in the structure.

The understanding of graphite influence led to the development of the combined carbon matrix, which produces higher mechanical strength properties, especially where the total amount of carbon has been kept lower than usual by the use of refined irons, or the use of steel in the mixture.

The lower the total carbon the greater the possibility there is of obtaining a combination with a higher silicon content than usual, that cooling speeds within certain limits may have no effect upon the structure, and the mechanical properties remain the same irrespective of wall thickness. The test results in Table 1 show how, with a variable percentage of total carbon content, and a constant amount of silicon, tensile and transverse figures are obtained which easily meet the most exacting specifications such as that of the British Admiralty.

Foundrymen do not appreciate, however, the great neutralising effect on the strength of the cast iron the size of the graphite flakes exerts, as shown in Series 1, or how easily wide variations can occur with iron of the same composition through the initial treatment of the iron during the melting period.

Continental investigations have shown that when cast iron is heated well above the ordinary melting temperature the graphite element in the final casting occurs in a finer state of division, and is generally associated with a structure of ferrite in the place of the well-formed pearlite and the normal graphite.

Attention to this fact has been drawn by the "Germ Theory," enumerated by the British Cast Iron Research Association, whereby a more complete solution of carbon present in the iron is obtained and which is afterwards precipitated in a finely divided form by the addition of a suitable graphite-provoking agent.

TABLE 1.

Si.	% T.C.	C.C.	Maximum Stress, in Tons.	Transverse, 1 in. × 1 in. × 12 in. Cwts.	Modulus of Rupture. Tons.
1·86	2·75	0·94	21·4	32·8	29·5
1·78	2·91	0·91	18·0	28·4	25·5
1·78	3·24	0·67	16·0	—	—
1·60	3·51	0·63	14·8	28·0	25·5
1·90	3·70	0·63	13·0	33·0	29·7

	%
Manganese	0·80
Sulphur	0·06
Phosphorus	0·40

The following specifications give a comparative outline of the requirements of the two leading surveys :—

BRITISH STANDARDS INSTITUTE.

		Tensile.			Transverse.				
Grade.	Thickness of Casting.	Dia. of Test Bar in In. as Cast.	Dia. of Test Bar in In. Machined.	Min. Breaking Load in Tons per Sq. In.	Dia. of Test Bar in In. as Cast.	Distance between Centres in In.	Min. Breaking Load in Lb.	Mod. of Rupture in Tons Sq. In.	Deflection in In.
A	Up to 1in.	0·875	0·564	12	0·875	12	1,185	24·1	0·12
A	Up to 2in.	1·2	0·798	11	1·2	18	1,950	23·1	0·15
A	Over 2in.	2·2	1·785	10	2·2	18	10,000	19·2	0·12
C	1in. to 2in.	1·2	0·798	9	1·2	18	1,600	18·9	0·12
C	Under 1in.	0·875	0·564	10	0·875	12	960	19·6	0·10
C	Over 2in.	2·2	1·785	9	2·2	18	8,950	17·2	0·10
Pipes for hydraulic power		—	—	—	2×1×42	36	3,360	—	< ½

Hydraulic Test.—Class A, 2,500 lb. per sq. in.
Class B, 3,300 lb. per sq. in.

BRITISH ADMIRALTY.

		Tensile.			Transverse.			
Grade.		Minimum Breaking Load Tons Sq. In.				Minimum Breaking Load, lbs.		
		S.	M.	L.		S.	M.	L.
Flywheels, Tools, propellers.	Test piece as B.S.I. Standards.	12	11	10	Test bars as B.S.I.	1,050	1,700	9,500
Cylinder covers, Diesel heads.	B.S.I.	14	13	11	B.S.I.	1,210	1,940	10,300
Main engines, steam gear cases, etc.	B.S.I.	13	12	10	B.S.I.	1,130	1,800	9,500
Auxiliary engines, steam, etc.	B.S.I.	16	15	12	B.S.I.	1,360	2,200	11,100

To confirm the effect which the total carbon exercises over the mechanical properties of cast iron, Table 2, of results obtained from a series of experiments where the total carbon was maintained at a constant figure and the silicon content varied, when compared with Table 1, where conditions are reversed, shows that the results are constant and that silicon *per se* had little or no effect.

TABLE 2.

Si.	% T.C.	C.C.	Maximum Stress in Tons.	Transverse, 1 in. × 1 in. × 12 in. Cwts.	Modulus of Rupture. Tons.
1·66	2·75	0·99	18·8	35·0	31·5
1·80	2·75	0·94	20·0	32·8	29·5
1·96	2·75	0·75	19·2	31·0	27·8
2·12	2·71	0·92	—	—	—
2·32	2·75	0·85	17·6	—	—
2·84	2·60	0·86	16·6	33·0	29·7
2·88	2·53	0·73	17·0	32·0	28·8
3·12	2·56	0·90	18·24	33·0	29·8
3·62	2·55	0·61	18·6	35·0	31·5

	%
Manganese	0·80
Sulphur	0·06
Phosphorus	0·40

Alloy additions to ordinary everyday mixtures of cast iron give remarkable changes in mechanical results to otherwise medium-strength iron. A comparison of such results is very clearly listed in the following results, which, in addition, give the effect of increasing sectional thickness upon the strength within the same mixture. This is of great importance, as small decreases in tensile strength, as the sections become thicker, indicate a uniform grain, and apart from special properties bestowed upon cast iron, certain combinations of alloys are valuable aids to the restriction of such variations to within narrow limits.

CHROMIUM CAST-IRON TEST BARS.

Analysis ..	T.C. 3·40	..	Si. 1·80	..	Mn. 0·78	..	S. 0·07	..	P. 0·18	..	Cr. 0·26

Tensile.			Transverse.			
Dia. of Test Bar in In. as Cast.	Dia. of Test Bar in In. Machined.	Minimum Stress in Tons per Sq. In.	Dia. of Test Bar in In. as Cast.	Distance between Centres in In.	Minimum Breaking Load in Cwts.	Modulus of Rupture in Tons per Sq. In.
0·875	0·564	16·8	0·875	12	16	36·5
1·20	0·789	14·2	1·20	18	28	38·0
2·20	1·785	8·33	2·20	18	122	36·9

CHROME-MOLYBDENUM CAST-IRON TEST BARS.

Analysis ..	T.C. 3·40	..	Si. 1·90	..	Mn. 0·72	..	S. 0·05	..	P. 0·13	..	Cr. 0·27	..	Mo. 0·39

0·875	0·564	20·48	0·875	12	12·2	27·3
1·20	0·798	16·6	1·20	18	26·4	35·3
2·20	1·785	13·58	2·20	18	140·8	30·8

NICKEL-CHROME-MOLYBDENUM CAST-IRON TEST BARS.

Analysis ..	T.C. 3·3	..	Si. 1·94	Mn. 1·0	..	S. 0·05	..	P. 0·12	..	Ni. 1·11	..	Cr. 0·22	..	Mo. 0·34

0·875	0·564	22·20	0·875	12	14·4	31·9
1·20	0·798	18·36	1·20	18	29·8	40·8
2·20	1·785	12·86	2·20	18	159·2	35·1

Specifications Affecting Solidity.

Solidity of section is of paramount importance, and in cases where castings are to be subjected to pressures of upwards of 1,000 lb. per square inch, and other cases with higher figures still, with water or kerosene as the liquid medium, some attention beyond the compliance with mechanical tests is needed. Generally speaking, soundness in cast iron has been associated chiefly with a correct balance of two elements in its composition, namely, silicon and carbon, together with the use of the best methods of moulding and pouring.

It is necessary, however, to briefly consider the sources of porosity, and on a broad classification these can be placed under two headings :—

1. Blowholes, entrapped gas, dirt, which can be readily eliminated by the use of hot metal, and clean, careful workmanship with correct moulding materials.
2. Porosity, which arises from the metal itself, such as shrinkage and contraction cavities, porous patches, cracks and openness of grain, which allow of minute weepages ; these are factors which arise out of the composition and behaviour during solidification of the molten metal, some phases of which have been mentioned already.

The question arises as to what constitutes an iron which will not have shrinking and cavity-forming properties ; so far there is still required a practical answer to this query, the theoretical possibilities have already been outlined where a eutectic composition of total carbon and silicon may possess a cooling speed which might have no effect upon the structure in so far as differences in section are concerned.

Such an iron suggests certain difficulties in the founding of it, due to a narrowed freezing range, which can be overcome, but it is in this shortened freezing range that greater solidity in the sections of a casting can directly arise. Confirmation of this has been proved by a comparison in the behaviour of a low-phosphorus content iron (under 0·3%) with one having a higher content. The shortened freezing range in the low-phosphorus iron causes the thicker sections of any casting to solidify with closer proximity in time factor to thinner sections, and produces soundness to internal pressure.

A further advantage of the use of such irons is that this soundness in section is not obtained at the expense of strength, but contrariwise ; tensile and transverse strength are somewhat higher, as shown by the following figures :—

MECHANICAL TEST RESULTS.
CAST DIAMETER, 0·875 IN. MACHINED DIAMETER, 0·564 IN.

T.C. %	Si. %	Mn. %	S. %	P. %	Maximum Stress in Tons per Sq. In.	Brinell No. Cr. of Bar.
3·27	2·00	0·89	0·04	0·07	18·6	229
3·27	2·12	0·91	0·04	0·76	14·0	229

TRANSVERSE TEST RESULTS.
CENTRES, 12 IN.

T.C. %	Si. %	Mn. %	S. %	P. %	Fracture Dia.	Load Cwt.	Modulus of Rupture, Tons.	Deflection, In.
3·27	2·00	0·87	0·04	0·07	0·860	15·08	34·1	0·162
3·27	2·12	0·91	0·04	0·76	0·860	13·5	30·7	0·132

Specifications and Machinability.

Strength in cast iron arises by virtue of the combined carbon present as a eutectoid composition, "pearlite," as in contrast to the presence of graphite plates, which are direct planes of weakness. It is, therefore, only logical that cast iron, having a large number of small flakes and a combined carbon content within the limits of machinability, will not only give the highest strength results, but will contribute to the maximum solidity of section.

Add to these factors a low phosphorus content, which means that the amount of hard, phosphide eutectic is limited, and a position is arrived at where high strength, maximum solidity, and ease of machining properties are obtained in one and the same metal.

METAL RESOURCES OF THE U.S.S.R.

IT is only since the Great War that the mineral wealth of Russia has been appreciated at anything like its true value. Before that time the iron ore deposits, for instance, were little known. A few of them only, those supplying iron to the state factories, had been prospected, but not very thoroughly. In 1913 an attempt was made to estimate the iron ore deposits, by Professor Bogdanovitch, who concluded that they amounted to about two milliard tons.

Further investigations show that these same deposits which formed the basis of Professor Bogdanovitch's calculations contain about 8,654 million tons of ore. This has been determined as a result of the extensive geological investigation into the natural resources of the Soviet Union carried out during the last few years, particularly during the development of the Five-Year Plan. In the case of the iron ore deposits, not only were the known ones found to contain more ore than was supposed, but many new deposits in different parts of the country have been discovered.

Some indication of the extent of these deposits will show the position in regard to iron ore deposits of the different districts; thus, for instance, the deposits of iron ore at Krivoi Rog are estimated at 1,142 million tons; this is three times as much as the deposit was estimated to be before the war. In the Urals Professor Bogdanovitch estimated the deposits to contain 200 million tons of iron ore, but the estimate to-day is 1,340 million tons, while the deposits in the Magnet Mountains are estimated at 305,500 million tons.

Great success has been achieved by the investigation of Titano-magnetic ores, which were not used in pre-war Russia because the process of their flotation was not understood. At the beginning of 1932 these deposits were estimated at 146,300 million tons. New deposits have been discovered in Bashkiria (Koniarovo Zagazinsk) which are estimated to contain 1,000 million tons of ore. Other new deposits have been found at Khalilovsk (Middle Volga Region) which are estimated at 397 million tons. It is claimed that the ores from these latter deposits have a high content of chromium and nickel.

In the Leningrad area the only important deposit known before the revolution was on the Kolsk Peninsula. This was estimated to contain 2,000,000 tons of ore. On further investigation in 1931-1932, however, deposits were discovered containing 49 million tons of ore of industrial character, having a content of 31% of iron. It is claimed that the total deposits in this area are now as much as 300 million tons. These ores have been found in two deposits, one on the northern bank of the Kolsk Fjord and the other in the neighbourhood of Lake Imandra, not far from the railway.

One of the most important discoveries made during the geological investigations during the last few years was that of the ore in the Kursk magnet anomaly. It is estimated that these deposits contain 200 million tons of ore having an average iron content of 30 to 40 per cent. Further new deposits have been discovered in Stari Oskol, the ore having an iron content of 50 to 67% similar to the ore of the Krivoi Rog. In this area the deposits so far investigated are estimated at 250 million tons. Rich iron deposits have also been discovered in west and eastern Siberia, in Yakutia, and the Far East. It is now estimated that the deposits of iron ore in Siberia are as much as 1,345 million tons. In 1917 Russia held tenth place in the world's resources of iron ore, but to-day the Soviet Union claim to hold first place. It is asserted that she has iron ore resources amounting to 260 milliard tons or 55% of the world's total estimated resources.

In addition to iron ore, several other minerals in common use are mined in Russia which in comparison with deposits found elsewhere are very large and important. It is claimed, for instance, that the Soviet Union possesses 65% of the total world resources of manganese, which are estimated at 588 million tons out of the total world estimated resources of 900 million tons. It is of interest to note that new deposits of manganese have been discovered nearer the metallurgical centres, and new investigations have shown that the known deposits of manganese in the Union are three and a half times greater than were known in pre-war Russia. In regard to non-ferrous metals, substantial deposits have been found. In 1917 the extent of the deposits of non-ferrous metals were not clearly known. It was roughly estimated at that time that there were 1,292,000 tons of copper, 579,000 tons of lead, 1,292,000 tons of zinc, and 5,500 tons of nickel, but as much as 20 to 30% of these figures were of possible deposits. The investigations have shown that to-day the known deposits of copper in the Union are ten times greater, of lead 3.8 times greater, and of zinc 4.3 times greater. Of the deposits of copper now known, which are estimated at 13.6 million tons, 60% are situated in Kazakstan, while new deposits have been discovered in Central Asia, Transcaucasia, Siberia, and the Urals. In regard to lead and zinc deposits, it is claimed that those at Kara-Tau are comparable in quality and extent to the deposits in the Missouri region of North America. Additional new deposits of poly metallic ores have been discovered in Central Asia, the North Caucasus, the Far East, and Kuznetsk Basin. Substantial deposits of nickel have been found. The estimated contents of the known deposits are stated to be 26 tons, but possible deposits are estimated at 153,000 tons, while prospected deposits at Khalilovsk are roughly estimated at 2,000,000 tons.

Personal.

Mr. John Fry, Director of Fry's Metal Foundries, Ltd., informs us that the firm has erected a new diecasting foundry adjoining the smelting works at Merton Abbey, where operations will be conducted under model conditions permitting a better, quicker, and more efficient service.

In future all correspondence relating to diecastings should be directed to Fry's Diecastings, Ltd., Prince's Road, Merton Abbey, London, S.W. 19; telephone, Mitcham 2041-2-3; telegrams, Frycas, Phone, London. Visitors to the works alight at Collier's Wood, on the Morden Tube railway.

The British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C. 4, have removed from their Birmingham Office and Warehouse at 21, Barwick Street, to Lawley and Landor Streets. The new telephone number is Aston Cross 5865-6.

Reviews of Current Literature.

Sampling and Analysis of Cast Ferrous Metals and Alloys.

THIS is a second edition of Research Report, No. 72, issued by the British Cast Iron Research Association in August, 1929, the object of which was to reduce difficulties arising from discrepancies in chemical analysis, taken in different laboratories on similar materials, by the recommendation of certain methods of sampling and analysis. The value of the report originally issued is indicated by the rapid exhaustion of the edition, and in the new edition the opportunity has been taken to incorporate methods for the estimation of special elements, either present in the materials of which castings are made, or added during the course of manufacture. The increasing use of such elements as nickel, chromium, and molybdenum in cast irons, the presence of titanium and vanadium in certain types of pig iron, and the addition of aluminium and other special elements for particular purposes, render standard methods of analysis of considerable importance.

The methods described in this work are applicable in the analysis of steels, and may be used without change to all ferrous metals. They are intended for use in works and other laboratories engaged in conducting acceptance tests on raw material and materials in process of manufacture, and the use of standard irons as a check upon analytical methods is strongly recommended.

In this work the methods recommended enable ferrous material to be examined quantitatively for any given elements, the presence of which is either known or suspected. Where two special elements are present the estimation of one of which is likely to interfere with that of the other a suitable alternative is given; while in cases of complex alloys, where it may be desirable to remove the iron, an ether separation is provided. It is of interest to note that the application of the methods is indicated for a complex alloy containing a small quantity of many special elements.

In this edition analytical methods for ferrous metals only are given, the matter relating to the sampling and analysis of metallurgical coke, coal dust, blackings, etc., have been transferred to the report, to be issued later, on recommended methods for the examination of foundry fuels, sands, and refractories.

This work has been prepared by the Tests and Specifications Sub-Committee of the Association's Research Committee, and has been approved for issue by the Council.

Copies may be obtained from the British Cast Iron Research Association, 21-23, St. Paul's Square, Birmingham. Price, 10s. 6d.

Special Steels.

SINCE the discovery of manganese steel by Sir Robert Hadfield in 1882, the development of special steels has advanced at a rapid rate. It was appreciated by metallurgists throughout the world that the success resulting from alloying steel with manganese might result in equal success when alloyed with other elements; thus this initial discovery opened an extensive field of research on special steels and, incidentally, has materially increased the application of steel. So much work has been done on special steels and so many treatises and papers written on the subject that the student of metallurgy is likely to be bewildered by the complexity and vastness of the field covered. With increasing knowledge of the subject, its complications become more apparent, and continual research has become more essential than ever because, as Sir Robert Hadfield states in a foreword, the future march of civilisation depends largely upon the scientific understanding, handling, and control of the qualities of iron.

In this book the author has sought to collect information in order that the student, operator, and user of special steels will have available a concise technical survey of the nature and scope of this important branch of metallurgical science. The scope of the work is comprehensive, and because of this it has only been possible to review briefly the current knowledge and practice in this field, but it is presented in such a concise and admirable form that it will benefit all who desire information on alloy steels.

The first edition of this work was published in 1923, and during the intervening time a number of additions to alloy steels for various commercial applications has necessitated the introduction of an appreciable amount of new text in this, the second, edition. The general trend, however, is towards standardisation and simplification of existing alloys, and in an endeavour to apply those that are less costly, provided there are adequate properties.

The book is based largely upon the work of Sir Robert Hadfield, a full list of whose papers and addresses is given in an appendix. Keeping in mind that there are 205 pages in which the author has sought to cover the field, this concise exposition on the constitution, manufacture, working heat-treatment and applications of alloy steels, bringing, as it does, a large subject into a comparatively small compass, cannot fail to be of value to students, engineers, designers, operators, and users of special steels.

By T. H. BURNHAM, B.Sc., A.M.I.Mech.E., M.I.Mar.E. with a Foreword by Sir Robert Hadfield, Bt., published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London. Price 12s. 6d. net.

Proceedings of the Institution of Welding Engineers. Vol. V.

THIS volume contains the seven papers read during the first half of the Session, 1932-33, September to December, at the ordinary general meetings of the Institution. The papers cover a wide range of welding applications, and include "The Testing of Fusion Welds in the Laboratory," by L. W. Schuster, M.A., M.I.Mech.E., M.I.E.E.; "The Radiographic Examination of Welds," by R. A. Stephen, M.Sc.; "Cutting Steel with Oxygen Machines," by C. G. Bainbridge, A.M.I.Mech.E.; "Eye Protection in Welding Operations," by Raymond R. Butler, M.Sc., F.I.C., F.C.S.; "Atomic Arc Welding and its Application," by J. A. Dorrat; and "The Essentials of Good Welding," by A. G. Walker. The discussions resulting from the papers are also published, and these assist in making the volume valuable.

Elementary Metallurgy for Beginners.

IT is difficult to appreciate what degree of metallurgical knowledge is required for the various branches of engineering, but we are inclined to think that the more engineers become acquainted with the fundamental principles of metallurgy, the more rapidly will developments be effected. Apparently many engineers know little about the materials with which they are so closely associated that an elementary book of this character cannot fail to provide useful information. In a condensed book such as this, however, the author has found a difficulty in dealing with the subject even in an elementary way. It is practically impossible to deal adequately with metallurgy in space provided by 151 pages, and the author's difficulty has been to make the best use of the space available.

When information is condensed there is always the likelihood of a wrong interpretation of that which is given. In this book, however, the author presents a general account of metals used in engineering with the object of establishing a link between metallurgical theory and engineering practice. The requirements of the engineer become more exacting every year, and it is very necessary that he should keep in touch with the developments of the metallurgists to meet his particular needs.

This book should prove useful to all students of engineering, and should give them a desire for further information as they advance in the field of engineering chosen.

By G. F. C. GORDON, M.A., A.M.I.C.E., M.B.H.I. Published by Messrs. Constable and Co., Ltd., 10-12, Orange Street, London, W.C. 2. Price, 8s. 6d. net.

Recent Developments in Tools and Equipment

Square Ingot Turning Lathe.

IT is questionable whether any branch of the iron and steel industry necessitates greater care and more skilful operations than in the manufacture of high-grade steels. With increasing demand for these special steels, methods have been improved in order to satisfy the more exacting specifications and tests now required for all kinds of alloy steels. This has necessitated the installation of the most modern plant and machinery, with the object of obtaining high-quality products at the lowest possible cost. The demand has been of such a character that open-hearth and electric furnaces have largely superseded the old cementation and crucible furnaces, and the ingots now produced are much larger than were formerly customary.

The use of larger ingots in these alloy steels has brought its own special problems, and the question of their shape has assumed considerable importance. The increasing quantities of special steels needed are responsible for the shape of these ingots being brought into prominence. In the mass production of ordinary steel it is generally assumed that the problem has been solved by using heavy, square ingots, and this is the practice adopted by all large steel works.

With ordinary steel, however, the crude ingots are used in their original state, with their casting skin exactly as it was immediately after drawing. It has been found that the deleterious influences of a defective casting skin in such ingots can be overcome, since a welding heat can be employed in the reheating furnace which eliminates defects and enables the ingot to produce an acceptable finished product. Investigation has shown that this practice is not possible with high-grade steels, as defects in the casting skin of the ingot give rise to inferior finished products, since many of these steels cannot be welded.

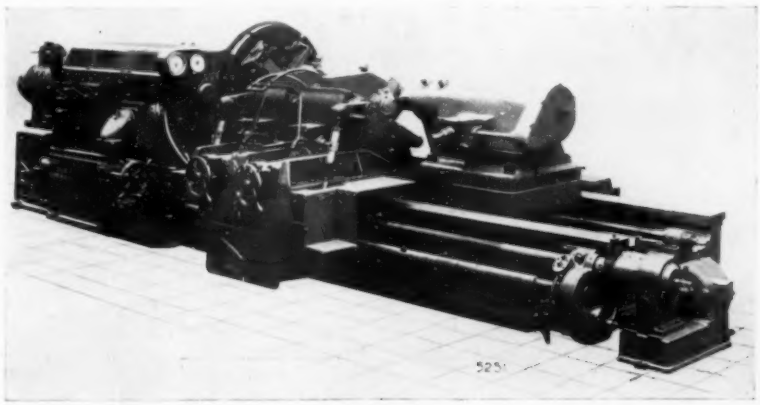
It was soon found that it was necessary to determine whether a particular grade of alloy steel could be heated above 1,050° C., so as to prevent the steel reaching the subsequent working phases in burnt or cold state. Very gradual heating is necessary with special steel to reduce the losses by oxidation. It was also recognised that square ingots yielded better results if they were first carefully dressed or planed by hand, the object being to remove all external defects.

The removal of the casting skin and deeply rooted surface cracks from square ingots is now regarded as essential to secure high quality of finished products in alloy steels, and in order that this operation can be performed satisfactorily, and at a low relative cost, Messrs. Craven Brothers (Manchester), Ltd., have recently designed and built several square ingot turning lathes, one of which is illustrated above.

This machine is specially designed to remove all surface defects from square or substantially square steel ingots prior to the rolling operations, and is the only machine of its type built in this country. Its use enables the square ingot to be machined with maximum economy and minimum loss of metal and power. The construction is such that any form of ingot, either taper or parallel, with flat, concave, or convex sides, can be readily machined, the desired shape being produced automatically without change of cams. The adjustment from one size and taper of ingot to another is extremely simple, occupies little time, and is substantially the only alteration in setting required.

The actual machining of the ingot is performed by cutting tools so mounted that they automatically preserve the correct cutting and clearance angles in relation to the sides and corners of the ingot, thus giving free cutting and maximum tool life. In addition to dealing with square ingots the machine can be arranged to deal with rectangular, oblong, or oval cross-sections, up to a ratio of 3 : 2 between the long and short sides. This is accomplished by cams, which are easily changed, and a reduction gear.

The ingot is mounted in the lathe in the usual way, the square header on the large end being gripped in special jaws on the fast headstock faceplate, and the small end carried on a centre in the loose headstock barrel. The saddle carries two transverse rocking tool slides, actuated by cam motions through adjustable levers, which impart



Square ingot turning lathe.

the rectangular shape to the ingot, the taper being produced by a tangent bar at the rear of the machine bed.

The turning tools are carried in swivelling holders, mounted on the transverse slides, and rock about their point above and below the horizontal, thus retaining constant cutting rake and clearance angle in relation to the sides and corners of the ingot as it revolves. Convenient means are provided for adjusting the action of the tool slides to produce flat, concave, or convex sides, and also to set the ingot in correct relation to the tools.

The machine is built in three sizes, to deal with ingots up to 8 in., 12 in., and 20 in. maximum square respectively, and the makers claim for it the following advantages :— Easy removal of local circumferential defects with minimum loss of metal, time, and power ; removal of a minimum total amount of metal from the ingot by virtue of accurate and easy setting of the tool slides and tools in relation to the ingot form ; high output with indifferently skilled labour, due to automatic production of ingot form ; continuous automatic cut on ingots with flat, concave, or convex sides ; simplicity of adjustment to all sizes of ingot ; and adaptability for machining rectangular shapes other than true squares.

There is a completeness about this machine that is altogether admirable and in its present form it provides an excellent example of the experience of the machine tool designer and illustrates the progress being made in the production of rigid machines designed to meet special requirements.

Electric Furnaces.

Notes on recent installations built by Electric Resistance Furnace Co., Ltd.

CONSIDERABLE progress has been made in the low-temperature treatment of metals in electric furnaces, with a view to improving the uniformity of temperature distribution and increasing the rate of heat transfer. This has been accomplished by the application of efficient high-speed fans, enabling a forced circulation of the furnace atmosphere to be obtained. This treatment has been adapted to the tempering of steel parts, the annealing of metals, such as zinc, aluminium, copper, and brass, and to the hardening of heat-treatable aluminium alloys.

Fig. 1 is an illustration of one of the largest furnaces of this type yet built. It is rated at 66 k.w., and has an effective working chamber, 4 ft. 6 in. deep × 3 ft. 6 in. diameter. The fan impeller is of the patented Gill screw type, and is located in the lid of the furnace. It has a diameter of 27 in., and will deliver 17,000 cub. ft. of air per min.

The importance of the design of fan cannot be overstressed in this connection, as upon it depends the rate of heat transfer and the evenness of temperature. The curves shown in Fig. 2 are actual test figures, which indicate comparative performances of the Gill fan and efficient centrifugal fan. It will be noted that a slight increase in resistance to the passage of air in the case of the centrifugal

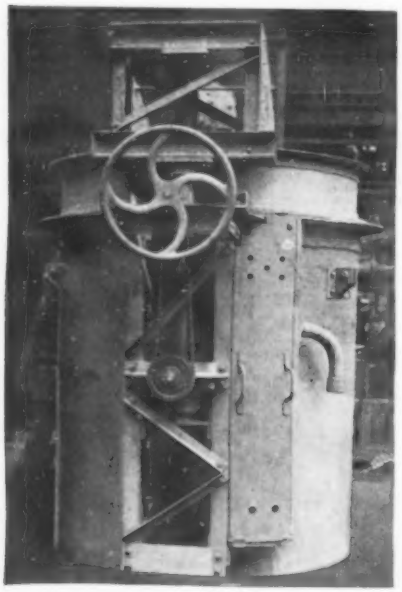


Fig. 1.—66 k.w. Vertical tempering furnace showing details of lid-operating gear.

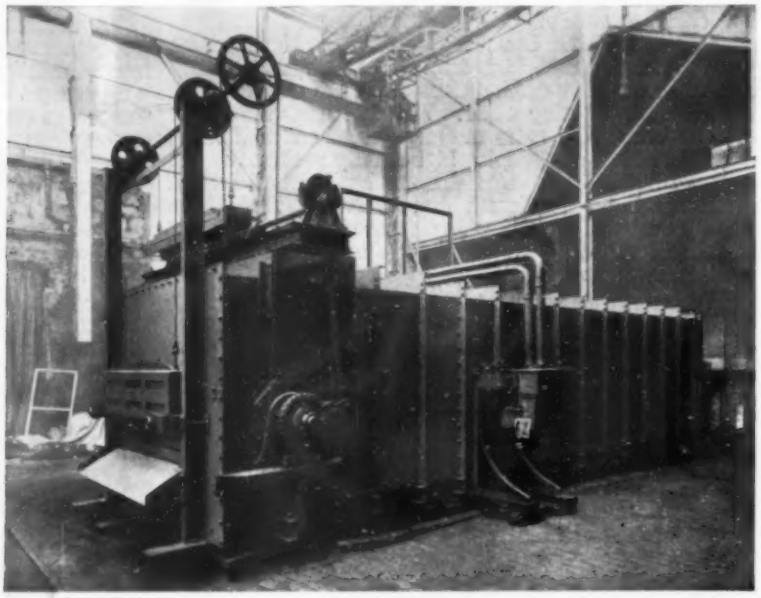


Fig. 3.—240 k.w. Continuous conveyer-type furnace. Oil-immersed main circuit breaker mounted at side. Structure for contactor switchgear on roof.

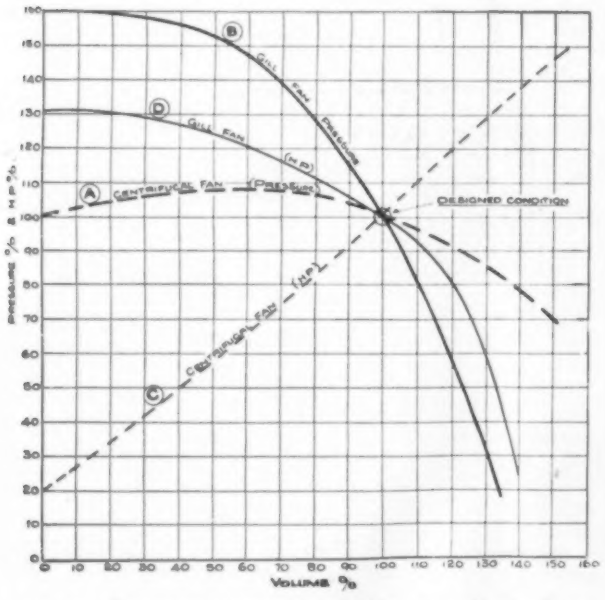

B
GILL FAN PRESSURE
D
GILL FAN (H.P.)
A
CENTRIFUGAL FAN PRESSURE
DESIGNED CONDITION
C
CENTRIFUGAL FAN (H.P.)
PRESSURE % & H.P. %
VOLUME %
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

Fig. 2.—Comparison between characteristic of performance for typical centrifugal fan and Gill screw fan.

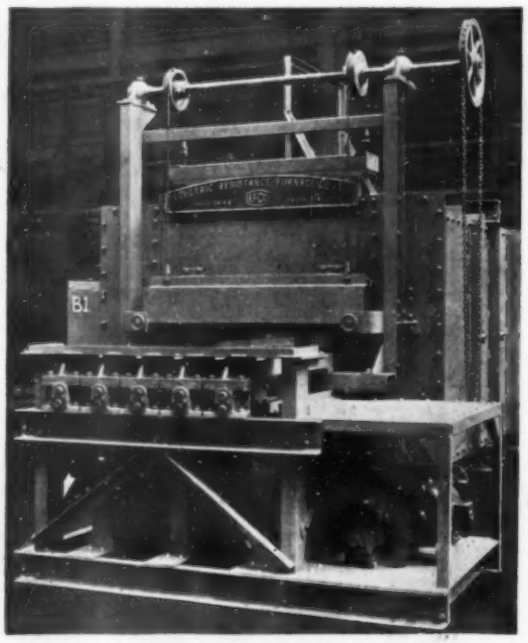


Fig 4.—170 k.w. Continuous pusher-type hardening furnace.

fan causes complete cessation of flow, while only a very slight diminution in volume occurs when using the Gill fan. In furnace practice, where resistance to air flow can vary appreciably, the advantage of a fan which is insensitive to considerable changes in pressure cannot be over-estimated.

The advantages of continuous heat-treatment are being rapidly appreciated, as it is the only means of ensuring accurate repetition of results, and Fig. 3 represents a continuous plate conveyer-type furnace suitable for the treatment of small parts. It has a heated chamber, 26 ft.

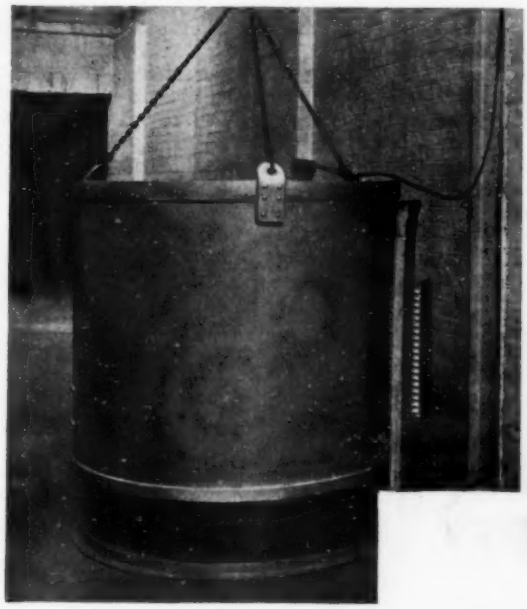


Fig. 5.—"Efco" bright annealing furnace for coils of wire and strip.

long, 5 ft. 3 in. wide, and has a maximum input of 240 kilowatts. At the working temperature, this furnace gives an output of 300 lb. of work per hour.

A group of three recently constructed pusher-type furnaces for the hardening of bushes, links, camshafts, etc., is shown in Fig. 4. The work is propelled through the furnace by means of multiple cam-operated pusher gear, the charge moving through profiled skid rails or being supported on heat-resisting alloy shoes. In certain instances, the work is quenched automatically in a tank which is provided with a Gill pump, ensuring circulation of the quenching medium. The work falls on to a conveyer in the quench tank, and is delivered by this means on to a discharging table.

Much progress has been made in the application of controlled atmospheres to electric heat-treatment.

The illustration Fig. 5 represents a bell-type furnace installed for the bright annealing of brass and nickel-silver strip and wire in the form of coils. It operates by a special patented process, which has been found the only satisfactory method for retaining a mirror-bright finish on these materials during batch annealing. It automatically compensates for loss of zinc on the surface, and previously red-stained material can be made to exhibit a perfectly yellow surface after treatment.

A Small Hardness Testing Machine.

A USEFUL little machine has been designed especially to meet the needs of research engineers, metallurgists, and others which is inexpensive, yet provides an accurate and reliable means of carrying out hardness tests on a wide variety of materials. It is suitable either for making Brinell hardness tests or for carrying out diamond hardness tests, and small ball indenters, as well as a four-sided pyramidal diamond point, are supplied with the machine for the purpose.

This machine, an illustration of which is shown in Fig. 1, is made at Birmingham by T. C. Howdon and Co. In its standard form it possesses many advantages. It is, for instance, fully equipped with ball and diamond indenters, microscope, etc., for making tests of materials of widely varying thickness and hardness. Any desired load, from 5 to 125 kilogs., by 5 kilog. increments, can be applied accurately to a specimen, thus enabling the machine to comply with the requirements of standard specifications. Loads can be applied slowly and progressively without any shock. The small mass of the load-measuring mechanism practically eliminates the effect of inertia. The machine is extremely easy to operate. After placing the specimen on the table it is only necessary to turn a handle, when, as soon as the indenter comes in contact with the specimen, the loading commences. A few further turns of the handle will produce the load required. The hardness of very thin materials can be determined, also the hardness of the case of surface-hardened specimens, by using the diamond indenter and applying a load of either 5 or 10 kilogs. The accuracy of the load-measuring mechanism can readily be demonstrated by suspending the machine on one of the ball indenters and hanging known weights on the base. In addition the machine is highly sensitive.

As will be seen in the illustration, two steel columns, attached to a cast-iron base, support the upper head, which carries the indenter spindle and the load-measuring mechanism. A table, mounted on a large screw, can move up and down between the columns; it is guided by bearings on the columns. The nut for the table screw is carried in the base of the machine and is rotated through bevel gears by a crank handle. The pressure of the load is taken on a ball-thrust bearing.

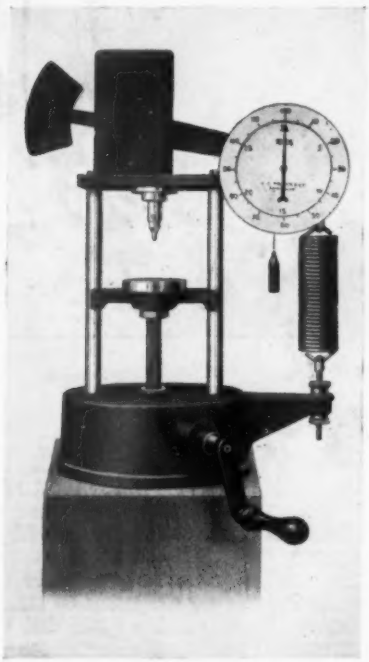


Fig. 1.—125 kilos. Brinell and diamond hardness testing machine.

The upward movement of the indenter spindle is transmitted to a horizontal lever through a connection which does not introduce friction, or any error, due to the angular displacement of the lever. The horizontal lever swings on carefully selected ball bearings, and at its extreme end is attached to a calibrated measuring spring. This measuring spring is subjected to only a small proportion of the total load applied by the machine. It has a high elastic limit and a long stretch. Moreover, it is so arranged that it cannot be stressed excessively, consequently it will maintain its accuracy over a long period of years. Its small mass eliminates inertia error. The movement of the horizontal lever rotates a pointer around a dial, the transmission being such that the pointer indicates the load in kilograms.

Two interchangeable measuring springs are provided. The larger one is suitable for measuring loads from 5 to 125 kilogs., whilst the smaller one is calibrated for loads

from 5 to 30 kilogs. Whichever spring is used, one turn of the pointer around the dial represents the full capacity of the spring. The smaller spring should be used therefore for all loads from 5 to 30 kilogs., as then a very open scale is provided and low loads can be applied with great accuracy. The dial is marked with two load scales corresponding to the capacities of the two springs. The springs can be interchanged in a few seconds. The lower anchorage of the spring has a screw adjustment whereby the pointer can be set to zero. A cover protects the vital parts of the spindle mechanism.

The standard microscope supplied with the machine is of excellent quality. It is portable and has a horseshoe-shaped base. Rack focusing adjustment is provided and an illumination attachment is fitted. The instrument is of high magnification, and the eyepiece is provided with a glass graticule reading to 0·005 mm. A suitable case is provided.

Rotor Forgings for Turbo-Generators.

The high-pressure and low-pressure turbine rotor forgings for the turbo-generators installed at Blackburn Meadows Power Station, recently opened by H.R.H. Prince George, were manufactured at the Vickers Works of the English Steel Corporation.

Forging a turbine rotor shaft for turbo-generators at the Vickers works of the English Steel Corporation.

The turbine rotor may perhaps be described as the most important component of the prime mover unit. It carries the turbine blades which are secured in grooves in the circumference, and the passage of the steam through these rows of blades causes the rotor to revolve at a high rate of speed (3,000 r.p.m.), and with the driving force necessary to impel the electric generators. It will be understood that the rotor is not only subjected to stress due to its own weight, no inconsiderable item, but to further centrifugal stresses due to its speed of rotation and the pull of the turbine blades.

It is, therefore, easy to see that the breakdown of such a part would be fraught with the most serious consequences. For this reason the steel must be absolutely sound, with the most carefully controlled heat-treatment. Furthermore, homogeneity of the material is also of great importance, since any departure from a high standard in this respect might throw the rotor out of balance and thereby cause vibrations to be set up, with dire results.

Plans have been made for the construction in Georgia of an artificial abrasive plant with a capacity of 10,000 tons of carborundum and 5,000 tons of alundum a year. The plant is to be built in the vicinity of the Rion Hydro-electric Station and is to be completed at the end of the second Five-Year Plan. This will make the third artificial abrasives plant in the U.S.S.R., the other two being in Leningrad and Cheliabinsk.

British Standard Specification.

Trolley and Contact Wire.

ONE of the earliest B.S. Specifications was that for trolley wire, which was published in 1905, and has remained unrevised right up to the present time. This old Specification, No. 23, was very brief, however, and for some years has been superseded by a series of specifications drawn up jointly by the Municipal Tramways and Transport Association and the Tramways, Light Railways, and Transport Association. These specifications have been of great benefit to both users and manufacturers, and after they had been in use for some years it was felt that they would be of still greater value if issued in the form of a British Standard, since large quantities of trolley wire are used, both by tramways and electrified railway systems in the Dominions, Colonies, and foreign countries where the specifications referred to do not penetrate. Consequently, B.S.S. No. 23-1905 has now been revised, the specifications issued by the Tramways Associations being taken as a basis. The revised B.S.S. is the most stringent specification in existence for this class of material, and takes full account of the great strides that have been made in recent years by cadmium-copper wire. Hard-drawn copper and bronze are also recognised as standard materials, each material having its own special advantages for use under particular conditions. The specification provides for both round and grooved sections of wire, and the range of sizes extends from the smallest tramway trolley wire to the largest railway contact wire in general use, or likely to be required for some time to come.

Copies of this revised Specification (No. 23-1933) may be obtained from the Publications Department of the Institution, 28, Victoria Street, London, S.W. 1. Price, 2s. 2d. post free.

Aeronautical Society Awards.

The Council of the Royal Aeronautical Society have awarded the silver medal of the Society to Mr. D. L. Hollis Williams, B.Sc., A.F.R.Ae.S., for his work in connection with the design of the long-range monoplane; and to Mr. A. H. R. Fedden, M.B.E., F.R.Ae.S., for his work in connection with air-cooled engines and particularly for his work in connection with the height record.

World's Record in Steel Smelting.

What is believed to be a new world's record has been set up by the United Steel Companies Limited steel-smelting furnaces at their Appleby Iron Company Limited plant at Scunthorpe, Lincolnshire.

Two weeks ago it was found necessary to meet an exceptional demand for steel ingots for the firm's plate mill. With the co-operation of the furnace crews and all other workers in the steel-smelting plant, the 300-ton steel-smelting furnace, which is of the tilting variety, was put to its maximum production. In the six days ending March 18 a production of 2,595 tons was achieved; there were 11 tappings of the furnace, each comprising three ladles of molten steel, containing approximately 78 tons. In the week ending March 25 the production from this one furnace was 2,515 tons, again beating the world record.

That this high rate of production is no mere flash-in-the-pan due to an intensive effort carried out for a few days only, is proved by the fact that the high production has now been maintained over a period of several weeks.

During the four-weekly period ending April 8 this furnace produced 10,042 tons of molten steel, thus creating a standard of British industrial efficiency which appears likely to lead the world for some time to come.

The plate mill and smelting shop of the Appleby Iron Company Limited is claimed to be the most up-to-date and best-equipped steel works plant in Europe, and the attainment of these very high productions is a powerful answer to the ill-informed cry which has been heard from time to time that the British iron and steel industry is not so well equipped as its rivals in other countries. It is noteworthy that the Appleby Plate Mill is now engaged not only on steel plates for consumption in this country, but upon substantial orders for delivery overseas.

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Boring Machines and Boring Mills.	George Richards & Co., Ltd., Manchester.
Gear Cutting Machines.	J. Parkinson & Son Ltd., Shipley, Yorks.
Grinding Machines.	The Churchill Machine Tool Co., Ltd., Manchester.
Turret & Capstan Lathes.	H. W. Ward & Co., Ltd., Birmingham.
Planers, Slotters, etc.	The Butler Machine Tool Co., Ltd., Halifax.
Plano Millers **Screwing Machines**	Kendal & Gent Ltd., Manchester.
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MARKET PRICES

ALUMINIUM.

98/99% Purity	£95	0	0

ANTIMONY.

English	£37 0 0 to £42	10	0
Chinese	26	0	0
Crude	19	0	0

BRASS.

Solid Drawn Tubes	lb.	8¾d.
Brazed Tubes	,,	10¾d.
Rods Drawn	,,	7¼d.
Wire	,,	7¼d.
*Extruded Brass Bars	,,	3¾d.

COPPER.

Standard Cash	£29	18	0
Electrolytic	34	10	0
Best Selected	32	5	0
Tough	31	15	0
Sheets	61	0	0
Wire Bars	35	10	0
Ingot Bars	35	10	0
Solid Drawn Tubes	lb.	9¼d.	
Brazed Tubes	,,	9¾d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	1	10½
‡Ferro Tungsten	,,	0	1	7½
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/– per unit	ton	34	2	6
NOMINAL: 4–6% Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL: 6–8% Carbon, scale 7/6 per unit	,,	21	17	6
NOMINAL: 8–10% Carbon, scale 7/3 per unit	,,	21	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	,,	33	17	6
Guar. max. 1% Carbon, scale 13/6 per unit	,,	37	17	6
§Guar. max. 0·7% Carbon, scale 15/– per unit	,,	42	17	6
‡Manganese Metal 96–98% Mn.	lb.	0	1	4
‡Metallic Chromium	,,	0	2	8
§ Ferro-Vanadium 25–50%	,,	0	12	8
§ Spiegel, 18–20%	ton	7	10	0
Ferro Silicon— Basis 10%, scale 3/– per unit	ton	5	17	6
20/30% basis 25%, scale 3/6 per unit	,,	8	10	0
45/50% basis 45%, scale 5/– per unit	,,	13	15	0
70/80% basis 75%, scale 7/– per unit	,,	19	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	14	17	6
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20–25%	ton	17	17	6

FUELS.

Foundry Coke—						
S. Wales	£1	0	0 to	1	2	6
Scotland	—			1	8	0
Durham	1	1	0 to	1	5	0
Furnace Coke—						
Scotland	—			1	5	6
S. Wales	0	16	0 to	0	16	6
Durham	0	13	0 to	0	13	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£47	0	0
*Commercial Ingots	37	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 8
*Cored Bars	,,	0	0 10

LEAD.

Soft Foreign	£10	17	6
English	12	10	0

MANUFACTURED IRON.

Scotland— Crown Bars, Best	£10	5	0
N.E. Coast— Rivets	11	0	0
Best Bars	10	10	0
Common Bars	10	0	0
Lancashire— Crown Bars	9	15	0
Hoops £10 10 0 to	12	0	0
Midlands— Crown Bars £9 15 0 to	10	0	0
Marked Bars	12	0	0
Unmarked Bars	—		
Nut and Bolt Bars £8 7 6 to	8	12	6
Gas Strip	10	12	6
S. Yorks— Best Bars	10	10	0
Hoops £10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "T brand, 1 in. dia. and up —Solid	lb.	8d.
*Cored Ba	,,	10d.
†Strip	,,	10¼d.
†Sheet to G.	,,	10½d.
†Wire	,,	11½d.
†Rods	,,	10½d.
†Tubes	,,	1/3½
†Castings	,,	1/1½
†10% Phos. Cop. £3 B.S.		
†15% Phos. Cop. £35 e B.S.		
†Phos. T 5%) £30 English Ingots.		

PIG I[illegible].

Scotland— Hema M/Nos.	£3	6	0
Foun No. 1	3	10	0
,, No. 3	3	7	6
N.E. Coast— Hematite No. 1	3	0	0
Foundry No. 1	3	1	0
,, No. 3	2	18	6
,, No. 4	2	17	6
Cleveland— Foundry No. 3	2	18	6
,, No. 4	2	17	6
Silicon Iron	3	1	0
Forge	2	17	0
Midlands— N. Staffs Forge No. 4	3	1	0
,, Foundry No. 3	3	6	0
Northants— Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	3	1	0
,, Foundry No. 3	3	6	0
West Coast Hematite	3	6	0
East ,, ,, No. 1	3	0	0

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Billets Kr. 280-290	£15 10 0–£16	0	0
Wire Rods Kr. 265-320	£14 12 6–£17	12	6
Rolled Bars (dead soft) Kr. 185-210	£10 4 0–£11	11	0
Rolled Charcoal Iron Bars Kr. 290	16	0	0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£21	0	0
,, Brazery	19	0	0
,, Wire	—		
Brass	16	0	0
Gun Metal	18	0	0
Zinc	8	0	0
Aluminium Cuttings	74	0	0
Lead	9	0	0
Heavy Steel— S. Wales	2	5	0
Scotland	1	18	0
Cleveland	1	17	6
Cast Iron— Midlands	2	0	0
S. Wales	2	4	0
Cleveland	2	4	0
Steel Turnings— Cleveland	1	11	6
Midlands	1	4	6
Cast Iron Borings— Cleveland	1	2	6
Scotland	1	12	0

SPELTER.

G.O.B. Official	—		
Hard	£12	10	0
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Ship, Bridge, and Tank Plates Scotland	£8	15	0
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,, ,, (Marine) ,,	—		
,, ,, (Land), N.E. Coast	10	0	0
,, ,, (Marine) ,,	10	10	0
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails £8 10 0 to	8	15	0
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Hard Basic £8 2 6 and	8	12	6
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,, ,, ½ in. = ½ in.	,,	1/–

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English	157	15	0
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Eastern	163	15	0
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Rods	26	0	0
Battery Plates	—		
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